Sponsored by the Office of Naval Research (ONR)

ONR Decision-Support Workshop Series

Continuing the Revolution in Military Affairs (RMA)

hosted by the

Collaborative Agent Design Research Center (CADRC)
Cal Poly State University, San Luis Obispo, CA

in conjunction with

CDM Technologies, Inc.
San Luis Obispo, CA

Proceedings of Workshop held on June 5-7, 2001

at
The Clubs at Quantico, Quantico Marine Base
Quantico, VA

September, 2001

Preamble

In August of 1998 the Collaborative Agent Design Research Center (CADRC) of the California Polytechnic State University in San Luis Obispo (Cal Poly), approached the Office of Naval Research (ONR) with the proposal for an annual workshop focusing on emerging concepts in decision-support systems for military applications. The proposal was considered timely by the ONR Logistics Program Office for at least two reasons. First, rapid advances in information systems technology over the past decade had produced distributed, collaborative computer-assistance capabilities with profound potential for providing meaningful support to military decision makers. Indeed, some systems based on these new capabilities such as the Integrated Marine Multi-Agent Command and Control System (IMMACCS) and the Integrated Computerized Deployment System (ICODES) had already reached the field testing and final product stages, respectively.

Second, over the past two decades the US Navy and Marine Corps have been increasingly challenged by missions demanding the rapid deployment of forces into hostile or devastated territories with minimum or non-existent indigenous support capabilities. Under these conditions Marine Corps forces have to rely mostly, if not entirely, on sea-based support and sustainment operations. Operational strategies such as Operational Maneuver From The Sea (OMFTS) and Ship To Objective Maneuver (STOM) are very much in need of intelligent, real-time and adaptive decision-support tools to assist military commanders and their staff under conditions of rapid change and overwhelming data loads.

In the light of these developments, Dr. Phillip Abraham of the Logistics Program Office of ONR considered it timely to provide an annual forum for the interchange of ideas, needs and concepts that would address the decision-support requirements and opportunities in combined Navy and Marine Corps sea-based warfare and humanitarian relief operations. The first ONR Workshop (***Collaborative Decision Making Tools***) was held April 20-22, 1999 and focused on advances in technology with particular emphasis on an emerging family of powerful computer-based tools. The workshop concluded that the most able members of this family of tools appear to be computer-based agents that are capable of communicating within a virtual environment of objects and relationships representing the real world of sea-based operations. Keynote speakers included: VAdm Jerry Tuttle (USN Ret.); LtGen Paul Van Riper (USMC Ret.); RAdm Leland Kollmorgen (USN Ret.); and, Dr. Gary Klein (Chairman, Klein Assoc.).

The second Workshop (***The Human-Computer Partnership in Decision-Support***) held May 2-4, 2000, was structured in two parts: a relatively small number of selected formal presentations (i.e., technical papers) followed each afternoon by four concurrent open forum discussion seminars. Keynote speakers included: Dr. Ronald DeMarco (Assoc. Technical Director, ONR); RAdm Charles Munns (USN); Col Robert Schmidle (USMC); and, Col Ray Cole (USMC Ret., Program Manager ELB ACTD, ONR).

The third Workshop (***Continuing the Revolution in Military Affairs (RMA)***) held June 5-7, 2001, is the subject of these Proceedings. Copies of the proceedings of past Workshops are available free of charge from:

Collaborative Agent Design Research Center (CADRC)
Cal Poly (Bdg. 117T)
San Luis Obispo, CA 93407

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Opening Remarks
as a Foreword to the 3rd Annual Office of Naval Research Workshop

Good Morning! I would like to welcome you all to this third annual Collaborative Decision Support Workshop sponsored by the Logistics Program Office of the Office of Naval Research. I am Jens Pohl, Executive Director of the Collaborative Agent Design Research Center at Cal Poly University in San Luis Obispo, California. Our Center, and Cal Poly, has had the honor of hosting this Workshop since 1999, and I am very gratified to see such a large attendance this year.

One might well ask: Why should we have a Workshop on Collaborative Decision Support?; and: Why chose this year's topic ***Continuing the Revolution in Military Affairs***? The answers to both of these questions are in fact quite logical. Certainly, nobody would argue that the Information Age has brought far reaching changes.

- Technology is advancing at an unprecedented rate.
- We appear to be inundated by the shear volume of information. However, we need to examine our words carefully here, are we really talking about information or is it just data?
- Global connectivity has not only increased accessibility, but it has also greatly increased the complexity of most of our undertakings.
- Our expectations of what we believe that we, as individuals, are capable of achieving have greatly increased.
- And, it has become quite apparent that the value of each individual person has appreciated enormously in recent years.

It is to be expected that these changes will also have a profound impact on the way the military will conduct its business over the next decade. Not only will these changes be reflected in the weapons that will be used and the warfighting strategies that will be employed, but also, the kind of capabilities the military will require from its decision-support systems. It is therefore by no means an overstatement to say that we are in the middle of a Revolution in Military Affairs.

When we established our Center at Cal Poly more than 15 years ago we had a vision: ***We thought that it should be possible to utilize computers for more than just data-processing and visualization; - as an intelligent, collaborative assistant***. Today, after much work by many centers and groups around the world, this vision is rapidly becoming a practical reality. In this regard I would, in particular, like to recognize Dr. Phillip Abraham of the Office of Naval Research (ONR), who also shared this vision and saw the need to establish an Annual ONR Workshop Series on Collaborative Decision Support in 1999. He saw a compelling need to explore several questions that could have profound impact on military affairs:

- Could computers be more than dumb data-processors?
- Should the difference between data and information be re-examined?
- Could computers be intelligent tools collaborating with human users?
- Were new concepts, notions, and approaches required?
- Should existing entrenched schools of thought be challenged?

He established this Workshop Series as a means of accelerating the transition from a data-centric to an information-centric decision-support systems environment. Thank you Phil, for your foresight and support.

I believe that we can look forward to a most exciting and inspiring three days. The presentations and discussions will explore several important topics:

- The essential need for, and purpose of, experimentation.
- Practical innovations by some of our active and retired military commanders.
- Technical innovations leading to information-centric interoperability. In this regard, during the last session this afternoon, we will be presenting a live demonstration of interoperability in which seven multi-agent systems will collaborate in a typical expeditionary warfare scenario.
- And, what we need to do to clear some of the obstacles on the road ahead.

Now I would like to ask my colleague and friend, Col Tony Wood (USMC Ret.), to introduce our distinguished keynote speaker, Mr. Andrew Marshall, Head of the Office of Net Assessment, US Department of Defense.

Jens Pohl
Collaborative Agent Design Research Center, Cal Poly (San Luis Obispo)
Quantico, June 5, 2001

Third Annual ONR / CADRC Decision Support Workshop

June 5-7, 2001, Quantico, Virginia

The Office of Naval Research
&
The Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo

"Continuing the Revolution in Military Affairs (RMA)"

Theme A: **The Changing Role of the Military**
Theme B: **The Future of Decision Support**
Theme C: **The Transitional Period**

Tuesday, June 5: **The Changing Role of the Military** (Theme A)

Time	Activity
7:30	**Check-in and Registration Begins** Registration Desk open from 7:30 AM to 4:30 PM
8:30 - 8:45	**Opening Remarks and Welcome by Dr. Jens Pohl**, Executive Director, Collaborative Agent Design Research Center, California Polytechnic State University (Cal Poly), San Luis Obispo, CA.
8:45 - 9:45	**Keynote Address by Mr. Andrew W. Marshall**, Head, The Office of Net Assessment, The Pentagon.
9:45 - 10:00	**Break**
10:00 - 10:45	***"Military Experimentation: Considerations and Applications"*** **Col. Anthony Wood** (USMC Ret.), Director of Applied Research, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo.
10:45 - 11:30	***"Applying the Lessons of Hunter Warrior during Recent Operations in the Persian Gulf"*** **CDR Christopher Noble**, US Navy.
11:30 - 1:00	**Lunch**

Tuesday, June 5 ~ continued

Time	Activity	
1:00 - 1:30	***"Experimentation as a Compass for the Future"*** **Col. James Lasswell** (USMC Ret.), Senior Advisor, Marine Corps Warfighting Laboratory.	
1:30 - 2:00	***"Experimentation: Staying Ahead of Today's Threats"*** **Col. Ray Cole** (USMC Ret.), Demonstration/Program Manager, Extending the Littoral Battlespace ACTD.	
2:00 - 2:30	***"Insights into Optimum TTPs/SOPs for Battalion, Regimental, and Brigade Command and Control"*** **Jim Murphy**, Dynamics Research Corporation.	
2:30 - 2:45	**Break**	
	Concurrent Sessions (by rotation)	
	Session A	**Session B**
2:45 - 3:30 and 3:30 - 4:15	**Demonstration (CADRC):** ***"Interoperability at the Information Level"***	**Dr. Jens Pohl (CADRC):** ***"Information-Centric Decision-Support Systems"***
4:15	**End of Day 1**	

Wednesday, June 6: **The Future of Decision Support** (Theme B)

Time	Activity
8:15 - 8:45	**Introductory Remarks by Dr. Phillip Abraham**, Logistics Program Office, Office of Naval Research (ONR).
8:45 - 9:45	**Keynote Address by RAdm. Jay M. Cohen**, Chief of Naval Research, Office of Naval Research (ONR).
9:45 - 10:00	**Break**
10:00 - 10:45	***"Transformation and Joint Experimentation"*** **Dr. Theodore S. Gold**, Director, Joint Advanced Warfighting Program.
10.45 - 11:30	***"Situation Awareness (SA) in a Knowledge-Centric C2 Application Environment"*** **Lt Col. Robert Morris**, Col.Sel., US Army.

Wednesday, June 6 ~ continued

Time	Activity
11:30 - 1:00	**Lunch**
1:00 - 1:30	***"Perspective Filters as a Means for Interoperability Among Information-Centric Decision-Support Systems"*** **Kym Jason Pohl**, Senior Software Engineer, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo.
1:30 - 2:00	***"The Architecture of a Case-Based Reasoning Application"*** **Michael Zang**, Senior Software Engineer, Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo.
2:00 - 2:30	***"A Clustering Approach for Analyzing Complex Knowledge Bases"*** **Mala Mehrotra**, President, Pragati Synergetic Research Inc.
2:30 - 2:45	**Break**
2:45 - 3:30	***"SEAWAY Supply Mission Scheduling Using Computational Intelligence"*** **Dr. Russell Eberhart** , Associate Dean for Research, Purdue School of Engineering and Technology, Indiana University Purdue University Indianapolis (IUPUI).
3:30 - 4:15	***"Project Albert + Rolf 2010 = RED ORM: A US-Sweden Decision-Support Collaboration"*** **Dr. Alfred Brandstein**, Chief Scientist, USMC MCCDC.
4:15	**End of Day 2**

Thursday, June 7: **The Transitional Period** (Theme C)

Time	Activity
8:30 - 9:15	***"Designing Communications Software for Tactical Wireless Networks"*** **Dr. Thomas McVittie**, Principal Software Engineer, Mission Software Systems, Jet Propulsion Laboratory, California Institute of Technology.
9:15 - 10:00	***"Will We Ever Get to a Network-Centric Navy? DoD Aquisition System Adjustments and Reforms Necessary to Bring About the Successful Migration"*** **Capt. Scot Miller**, US Navy, Naval War College.

Time	Activity
10:00 - 10:45	***"The Value of Decision-Support Tools in the Aquisition Process"*** **Christopher Neff**, CINCPACFLT Logistics Office.
10:45 - 11:00	**Closing Remarks by Dr. Phillip Abraham**, Logistics Program Office, Office of Naval Research (ONR).
11:00	**End of Day 3**

Address:

The Clubs at Quantico
Quantico Marine Base
3017 Russell Road
Quantico, VA 22134

POC:

Mrs. Phyllis Whitlock
CDM Technologies, Inc.
Tel: (805)541-3750 Ext.235
Fax: (805)541-1221
E-Mail: Phyllis@cdmtech.com

About the Speakers

Dr. Phillip Abraham

Logistics Program Office
Office of Naval Research

Dr. Abraham is a Scientific Officer at the Office of Naval Research (ONR). For the past seven years he has managed the ONR S&T Logistics Program. During the previous five years he was in charge of the ONR 6.1 Structural Acoustics Program, the goal of which was minimizing emission/scattering of sound by submarines.

From 1982 until 1989 he was a member of the Naval Research Laboratory where he did research on fluid-structure interactions, and on wave propagation phenomena. He studied the propagation of acoustic waves in inhomogeneous and random media, and showed how to obtain results, to all orders, for both weak and strong perturbations. This work and work on reflection tomography were motivated by the need to detect passively or actively targets in the ocean.

Dr. Abraham started working for the Navy in 1974 at the Underwater Sound Laboratory in New London, Connecticut. There his research dealt with underwater acoustics, focusing on detection and localization of underwater targets. Among other topics he determined the influence of size on magnetic anomaly detection (MAD) of ferromagnetic targets. In addition, he and Dr. H. Moses used inverse scattering theory to generate new families of potentials for which the Schrodinger equation has exact solutions. These were useful later on in determining acoustic wave propagation in the arctic ice cap.

From 1970 until 1974, Dr. Abraham was an Assistant Professor of Physics at the University of Connecticut, where he taught and worked on Nonlinear Dynamics problems related to solitons.

During 1968-1970, Dr. Abraham was employed by Raytheon Company in New London, Connecticut. There he worked on acoustic imaging in fluid media using an exact analytic approach. A concurrent laboratory experiment yielded a visual image, on a TV screen, of an insonified submerged object. At that time, it was the first such image generated with acoustic waves.

From 1966 until 1968, Dr. Abraham was granted a Postdoctoral Research Associateship by the National Research Council. Located at NASA's Goddard Space Flight Center, he worked on propagation of charged particles, originating from solar flares, through the interplanetary magnetic field. The results of the theoretical work matched quite well with experimental results obtained from high-altitude balloon flights.

Dr. Abraham was awarded the Ph.D. in Physics by the University of Maryland in 1966. His thesis topic was in Solid State Physics, and it dealt with generating exactly solvable models of crystal lattices, which were used subsequently to check perturbation methods employed in the treatment of actual crystals.

Dr. Alfred Brandstein

Chief Scientist (SES-IV)
USMC MCCDC

Dr. Alfred George Brandstein holds a Bachelor of Science degree from Brooklyn College, with majors in Physics, Mathematics, and Astronomy, and a Ph.D. in Mathematics from Brown University. The topic of his doctoral dissertation was Function Spaces Related to hypo-Dirichlet Algebras.

Dr. Brandstein joined the U.S. Army's Harry Diamond Laboratories in 1972 after serving as a professor at the University of Conneticut. At Harry Diamond Labs, he engaged in research in the simulation of military communication systems and nuclear weapons effects. He transferred to the Analysis Support Branch of the Marine Corps Development Center in 1980 and served as Chief of that branch and as Deputy of the Plans Division. With the formation of the MAGTF Warfighting Center, Dr. Brandstein became Head of the Assesment Branch. During Desert Shield/Dessert Storm, he was Director of the Marine Corps Operations Analysis and Assessment Group (MCOAAG).

Currently, he is Scientific Advisor/Senior Analyst, a Senior Level (SES-4 equivalent) position for the Marine Corps Combat Development Command. While at the Development Center, he completed the Command and Staff College Non-Resident Program. Dr. Brandstein, who has authored several hundred professional papers, is the recipient of the Darcom Systems Analysis Award, the Marine Corps Meritorious Civilian Service Award, and the Superior Civilian Service Award. He is a former director of the Military Operations Research Society and a recipient of the Clayton Thomas Award for technical achievement. He has served on numerous national and international panels and boards in such diverse areas as directed energy, acoustics, seismology, lasers, and mathematics.

RADM Jay M. Cohen

Chief of Naval Research

Rear Admiral Jay M. Cohen became the 20th Chief of Naval Research, commanding the Office of Naval Research (ONR), on June 7, 2000. As the Chief of Naval Research, RADM Cohen manages the science and technology programs of the Navy and Marine Corps from basic research through manufacturing technologies.

In addition to his position as Chief of Naval Research, RADM Cohen also assumed the duties of Director, Test and Evaluation and Technology Requirements in the office of the Chief of Naval Operations, and Assistant Deputy Commandant (Science and Technology), Headquarters, US Marine Corps.

Rear Admiral Jay M. Cohen received his commission as an Ensign upon graduation from the United States Naval Academy in 1968, where he was a Trident Scholar. After graduation, he qualified as a Navy diver with the SEALAB Group in San Diego, CA. Following training at Submarine School, New London, CT, he reported to USS DIODON (SS 349) in San Diego for duty as Supply and Weapons Officer during an extended WESTPAC deployment. He next studied at the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution under the Navy's Burke Scholarship Program. He received a joint Ocean Engineering degree and Master of Science in Marine Engineering and Naval Architecture from MIT. Following Nuclear Power Training, he was assigned to the Engineering Department aboard USS NATHANAEL GREENE (SSBN 636) (BLUE) in New London. He was next ordered to duty as Engineer Officer aboard USS NATHAN HALE (SSBN 623) (BLUE) in overhaul at Bremerton, WA, subsequently changing homeport to Charleston, SC. Upon completion of that tour, he served on the staff of the Commander Submarine Force, US Atlantic Fleet, from which he reported to USS GEORGE WASHINGTON CARVER (SSBN 656) (GOLD) in New London as Executive Officer.

Rear Admiral Cohen commanded USS HYMAN G. RICKOVER (SSN 709) from January 1985 to January 1988. Under his command, RICKOVER completed a Post New Construction Shakedown availability in New London, changed homeport to Norfolk, VA, and completed three deployments. RICKOVER was awarded a Navy Unit Commendation, a Meritorious Unit Commendation, the SIXTHFLT "Hook'em" Award for ASW excellence, CINCLANTFLT Golden Anchor Award for retention excellence, the COMSUBRON 8 Battle Efficiency "E" Award, and was designated the best Atlantic Fleet Attack Submarine for the BATTENBURG CUP.

Following command, Rear Admiral Cohen served on the staff of Commander in Chief, US Atlantic Fleet, as senior member of the Nuclear Propulsion Examining Board, and the staff of the Director of Naval Intelligence at the Pentagon as Director of Operational Support.

Rear Admiral Cohen commanded USS L.Y. SPEAR (AS 36) and her crew of 800 men and 400 women from March 1991 to April 1993. During his tour, SPEAR was awarded the Submarine Force Atlantic Fleet Battle Efficiency "E" Award and conducted an unscheduled five-month deployment to the Persian Gulf in support of Operation DESERT STORM that included repairs to over 48 US and allied ships, recovery of an F/A-18 Hornet sitting in 190 feet of water off the coast of Iran, and humanitarian projects in Kuwait City. SPEAR received a Meritorious Unit Commendation for the deployment, which was the ship's first in eleven years. Additionally, SPEAR was the CINCLANTFLT 1991 Secretary of Defense Maintenance Award nominee and the only Atlantic Fleet tender recognized in two consecutive Golden Anchor competitions.

In April 1993, Rear Admiral Cohen reported to SECNAV staff for duty as Deputy Chief of Navy Legislative Affairs. In October 1997, he was promoted to the rank of Rear Admiral and reported to the Joint Staff for duty as Deputy Director for Operations. In June 1999, he assumed duties as Director Navy Y2K Project Office. In May 2000, he was ordered to duty as Chief of Naval Research.

Rear Admiral Cohen is authorized to wear the Defense Superior Service Medal and multiple awards of the Legion of Merit and Meritorious Service Medal. He is submarine and surface warfare qualified.

Col. Raymond Cole

USMC Ret.
Demonstration/Program Manager
Extending the Littoral Battlespace ACTD

Raymond Cole was born in Philadelphia, Pennsylvania. He enlisted in the Marine Corps and was commissioned in November 1971 after graduating with a Bachelor of Arts Degree in Economics from Virginia Polytechnic Institute and State University in Blacksburg, Virginia.

Mr. Cole served in a variety of command and staff positions with the 1st and 2nd Marine Divisions for almost eleven years. Subsequent tours included: Executive Officer, Marine Detachment, USS Saratoga, Instructor Amphibious Warfare School, and Executive Officer of Basic School Classes 5-79 and 3-80.

From July 1980 to July 1983, Mr. Cole served with the 2nd Marine Division, initially with 2nd Battalion, 8th

Marines as a Rifle Company Commander and Battalion Operations Officer, and then, as the Regimental Operations Officer, 8th Marines. He twice deployed to the Mediterranean and participated in operations to evacuate the Palestine Liberation Organization from Lebanon and in the subsequent peacekeeping mission.

Mr. Cole served as a Ground Combat Analyst at Headquarters Marine Corps from July 1984 to July 1987. He transferred to the Basic school in July 1987 and served as the Tactics Group Chief until July 1989.

In August 1990, Mr. Cole began his second tour with the 1st Marine Division, serving as the Division Operations Officer during Operations Desert Shield and Storm. After the war, he commanded the 1st Light Armored Infantry Battalion and served as a Battalion Commander in Los Angeles during the 1992 Riots. He assumed duties as the Division G-3 in 1992 and deployed to Somalia in December 1992 in support of Operation Restore Hope. Then, Colonel Cole commanded 1st Marine Regiment from July 1993 until January 1995 when he assumed interim duties as the Chief of Staff, I Marine Expeditionary Force.

Mr. Cole returned to Washington DC in June of 1995 and served as the Chief, Land and Littoral Warfare Joint Warfighting Capabilities Assessment Division, J-8, the Joint Staff. During this tour, Mr. Cole served as the Co-Executive Secretary for the 1996 Defense Science Board and the Modernization Panel Chief for the 1996 Quadrennial Defense Review.

During his active service, Mr. Cole attended the Marine Corps' Amphibious Warfare School and Command and Staff College and the National War College at Fort McNair during the academic year 1989-1990. Mr. Cole received personal decorations that include the Defense Superior Service Award, Legion of Merit with Gold Star and Combat Distinguishing Device, Meritorious Service Medal with Gold Star, Navy Commendation Medal, Navy Achievement Medal, and Combat Action Ribbon. In 1991, Mr. Cole was awarded the Navy League's "Holland M. Smith Award" for Operational Competence.

Mr. Cole retired from the Marine Corps in 1997 and joined Booz Allen & Hamilton where he worked as a Consultant to both the ELB ACTD and the Urban Warrior AWE. In June 1999, Mr. Cole assumed his present responsibilities as the Program/Demonstration Manager for the ELB ACTD. Mr. Cole serves in his present position as an IPA from the Potomac Institute for Policy Studies.

Mr. Cole is married to the former Dianne Casteel of Virginia Beach, Virginia. They have one daughter, Adrian, and three sons: Brian, Adam, and Mark.

Dr. Russell C. Eberhart

Associate Dean for Research, Purdue School of Engineering and Technology, Indiana University Purdue University Indianapolis (IUPUI)

Russell C. Eberhart is the Associate Dean for Research at the Purdue School of Engineering and Technology, Indiana University Purdue University Indianapolis (IUPUI). He is also Director of the Biomedical Research and Development Center and Professor of Electrical and Computer Engineering. He received his Ph.D. from Kansas State University in electrical engineering. In addition, he is co-editor of a book on neural networks, now in its fifth printing and co-author of Computational Intelligence PC Tools, published in 1996 by Academic Press. His recent book with Jim Kennedy and Yuhui Shi entitled, *Swarm Intelligence*, was published by Morgan Kaufmann/Academic Press in October 2000. Furthermore, he is Associate Editor of the IEEE Transactions on Evolutionary Computation and was recently awarded the IEEE Third Millenium Medal.

Dr. Theodore S. Gold

Director, Joint Advanced Warfighting Program, Institute for Defense Analyses

Dr. Gold's career has concentrated on the applications of technology to national security. He has conducted and managed R&D at a National Laboratory, served in government in the Department of Defense, provided technical services and strategic planning advice to government and industry clients, and led many end-to-end systems and architectural efforts.

Dr. Gold is currently Director of the Joint Advanced Warfighting Programs at the Institute for Defense Analyses, IDA. This new activity was established by the DoD to help develop and experiment with new joint operational concepts and capabilities.

Dr. Gold is a member of DoD's Threat Reduction Advisory Committee, the Defense Science Board, and for a four-year term, was Chairman of DoD's Ballistic Missile Defense Advisory Committee. His recent Defense Science Board activities include chairing studies of coalition warfare, rapid force projection, modeling & simulation, the transnational chemical and biological warfare threat, and cruise and ballistic missile defenses.

Prior to moving to his current position at IDA in March 1998, Dr. Gold had been President of Hicks & Associates, Inc. (H&AI). Before joining H&AI in 1987, Dr. Gold had established and managed a National Security Studies Group at Booz-Allen and Hamilton.

In the early 1980s, Dr. Gold served as Deputy Assistant to the Secretary of Defense responsible for chemical warfare deterrence and biological warfare defense programs. He was the first occupant of this position and worked closely with the military to improve the posture of our forces, while guiding DoD's research, development, and procurement activities in these areas. He was also a major participant in the nation's chemical arms control initiatives.

Before his government service, Dr. Gold held a variety of technical and management positions during a twenty-year career at Sandia National Laboratories. Much of his efforts at Sandia were directed toward helping ensure the safety, security, reliability, and control of nuclear weapons. He also designed weapon survivability, safing, and fuzing systems; led many system analysis efforts; conducted research in weapon effects; managed a large scale computing and programming center; and, developed energy technologies.

Dr. Gold received a BSEE degree from Renssalaer Polytechnic Institute, an M.S. degree in Electrical Engineering from the University of New Mexico, and a Ph.D. in Engineering from the University of California, Davis.

He is married to Dr. Sydell Gold. The Golds reside in McLean, VA and have three grown children: a daughter and two sons.

Col. James Lasswell

USMC Ret.
Senior Advisor
Marine Corps Warfighting Laboratory

James A. Lasswell has been the senior analyst for GAMA Corporation since June 1998. In this capacity, he has been responsible for a series of advanced concept wargaming as well as supporting the development of the Collin's Combat Decision Range under contract for the Marine Corps Warfighting Laboratory (MCWL).

A retired US Marine Corps Colonel, he was the Head of Experimental Operations at MCWL and served as Experiment Control for the seminal Hunter Warrior Advanced Warfighting Experiment during March 1997. In addition, he has over 10 years military experience in political, military, and strategic plans positions including serving as the Head of the Commandant's Staff Group, as well as additional duties that included serving as Co-chairman of two Office of the Secretary of Defense sponsored Revolution in Military Affairs Task Forces. Mr. Lasswell was the Marine Corps author for the Naval Services' strategic concept document titled, *Forward... From the Sea*, and is a frequent contributor to professional journals on future technology and conceptual issues.

Andrew W. Marshall

Head, The Office of Net Assessment
The Pentagon

Andrew W. Marshall is the Advisor to the Secretary of Defense for Net Assessment. Mr. Marshall founded the Office of Net Assessment, which provides Secretaries of Defense, other managers, and military commanders with assessments of military balancing, major geographic theatres, and mission areas. These assessments are designed to highlight existing or emerging problem areas or important opportunities that deserve top-level management's attention to improve the future US position in the continuing military-economic-political competition. Major asymmetries in the capabilities, organizations, operational concepts, and strategies of the US and all major actors relevant to the continuing competition in specific balance areas are addressed.

While working in the Office of the Secretary of Defense, Mr. Marshall has conducted discussions with groups in other countries performing similar or related assessments, including major, continuing interchanges with the governments of Australia, France, Germany, Israel, Japan, and Sweden. Mr. Marshall has encouraged and participated in the development of strategic planning, in particular, the competitive strategies initiative. From 1986-1988, he was the co-chairman of the Future Security Environment Working Group on the President's Commission on Integrated Long-Term Strategy. In addition, he was Chairman of the Nuclear Strategy Development Group from 1984-1985.

Between April 1972 and October 1973, Mr. Marshall was a member of the National Security Council Staff where he established and directed the NSC Net Assessment Group. This group provided staff support of the National Security Council Intelligence Committee. During this period, he monitored the implementation of the November 1971 reorganization of the Intelligence Community ordered by President Nixon.

Mr. Marshall was at RAND Corp. from 1949 until 1972. While at RAND, his major areas of research included: nuclear targeting; strategic warning; Monte Carlo simulation methods; analysis of Soviet military programs; application of organizational behavior theory to military analysis; and, the development of strategic planning concepts, including strategy for long-term US-Soviet political-military competition.

Mr. Marshall holds an A.M. in Economics from the University of Chicago (1949) and attended the University of Detroit (1940-41) and Wayne University (1943-1945).

Dr. Thomas McVittie

Principal Software Engineer
Mission Software Systems
Jet Propulsion Laboratory
California Institute of Technology

Thomas McVittie is a principal software engineer at NASA's Jet Propulsion Laboratory. His research interests include highly reliable object-based distributed systems and fault tolerant system architectures.

McVittie has a Ph.D. in Electrical and Computer Engineering from the University of California at Santa Barbara. He is the systems architect for the Defense Information Infrastructure (DII) Common Operating Environment (COE) Kernel and the principal designer of the Shared Net, which is an object-based information sharing system designed for the USMC.

Mala Mehrotra

President
Pragati Synergetic Research Inc.

Mala Mehrotra is the founder and President of Pragati Synergetic Research, Inc, a small business located in Cupertino, CA. The company has recently relocated from VA to the Silicon Valley. Since its inception eight years ago in VA, Pragati Inc. has been performing high-end artificial intelligence research for mainly government contracts. Its clients have been DARPA, Air Force, Navy, NSF, DOT (Department of Transportation), and several others.

Mala Mehrotra has an M.S. degree with a concentration in artificial intelligence and parallel computing from the College of William and Mary in VA. In addition, she has an M.S. in Nuclear Physics from Delhi University, India. Her B.S. degree was in Physics (Hons) from Calcutta University, India.

As an on-site contractor at Systems Validation and Methodology Branch (SVMB), NASA Langley Research Center in Hampton, VA from 1989-93, Ms. Mehrotra developed various methodologies for software engineering of knowledge-based systems. She has been the principal architect of the prototype Multi-ViewPoint Clustering Analysis Tool (MVP-CA), that partitions large and complex knowledge-based systems into meaningful units for the purpose of software engineering them. She has been the recipient of several SBIR awards from NASA, NSF, and AF, relating to the development and application of the MVP-CA tool. Her presentation will describe salient aspects of her technology as well as her experiences in analyzing IMMACCS, a multi-agent system for command and control developed by the CADRC.

Capt. Scot A. Miller

United States Navy
Naval War College

Ensign Miller entered the Navy from the US Naval Academy in 1978 and was designated a Naval Aviator in December 1979. His first operational unit was Patrol Squadron FORTY at NAS Moffett Field, CA, flying the P-3C Orion. He deployed three times to Misawa, Japan, with detachments to Cubi Point, RP, and Diego Garcia, BIOT.

From 1983-1986, LT Miller served as a flight instructor at Training Squadron THREE, flying the T-34C. In 1985, he was named squadron Instructor of the Year. In 1986, LT Miller reported aboard the USS CARL VINSON (CVN-70) in Alameda, CA as an aircraft launch and recovery officer. He also qualified and stood regular watches as a Tactical Action Officer. LT Miller deployed twice to the Indian Ocean and North Arabian Sea. From 1988-1989, LCDR Miller served as Aide and Flag Lieutenant to the Commander, Operational Test and Evaluation Force in Norfolk, VA.

After training at the Fleet Replacement Squadron, LCDR Miller returned to Patrol Squadron FORTY at Moffett Field, CA. He served as the Administrative, Tactics, and Maintenance Officer and deployed to Misawa, Japan, with a detachment to Diego Garcia, BIOT. In 1994, CDR Miller was assigned as the Modeling and Simulation Officer at CINCPACFLT in Pearl Harbor, HI. He tested modeling and simulation capabilities on board naval ships.

CDR Miller reported aboard the staff of Commander, THIRD Fleet on the USS CORONADO, home ported in San Diego, CA in 1997. He was the first permanently assigned Director of the Sea Based Battle Laboratory and coordinated numerous limited objective experiments, Fleet Battle Experiment ECHO, and a Marine Corps advanced warfighting experiment. In 1999, CDR Miller became the first Director of the COMTHIRDFLT Network Centric Innovation Center. In this role, he worked to improve fleet use of existing IT infrastructure.

Besides a B.S. in Operations Analysis from the United States Naval Academy (1978), CAPT Miller holds an

MBA from the University of West Florida (1986) and an M.S. in Operations Analysis from the Naval Postgraduate School (1994). He is married to the former Wendy Barry of Albemarle, NC. They have one son, Jeffrey.

CAPT Scot Miller is currently a student at the Naval War College in Newport, RI. Recently, CAPT Miller served as the first Director of the Network Centric Innovation Center for COMTHIRDFLT, where his team assisted deploying battle groups and amphibious ready groups to improve employment of their new IT infrastructure. Previously, he was the first director of COMTHIRDFLT's Sea Based Battle Laboratory from 1997-1999. His experience as the Modeling and Simulation Officer at CINCPACFLT from 1994-1997 led to his billets at COMTHIRDFLT. CAPT Miller coordinated a variety of technology and process innovations and experiments during this time frame. He supported several Decision-Support design proposals for operational commanders and worked closely with several future information management initiatives. During several Joint Task Force exercises and Fleet Battle Experiment ALFA, he introduced operational level modeling and simulation support to the decision maker at sea. CAPT Miller is an enthusiast and novice facilitator for Group Support Systems. CAPT Miller just completed an Advanced Research Project at Naval War College which focused on modifications and reforms necessary to migrate the Navy to a more capable network-centric force. Upon graduation, CAPT Miller has been ordered to the Naval Warfare and Space Systems Command in San Diego.

LTC Robert C. Morris Jr.

Col. Sel.
US Army

Lieutenant Colonel Morris graduated from the Virginia Military Institute receiving his commission in Infantry in 1979. His initial assignment was with the 1st Battalion, 31st Infantry in Korea where he served as a Rifle Platoon Leader, Company Executive Officer, and Scout Platoon Leader. LTC Morris was next assigned to the 2d Battalion (Ranger), 75th Infantry in Fort Lewis where he served as a Rifle Platoon Leader, then as Battalion Support Platoon Leader supporting Operation Urgent Fury. Following the Infantry Officer Advance Course, LTC Morris was assigned to the 4th Battalion, 325th Infantry (Airborne) Battalion Combat Team as the Battalion S-4. He returned with the unit to the 82d Airborne Division and Fort Bragg as a Company Commander and later served as the Battalion S-3. LTC Morris served three years with the Joint Special Operations Command at Pope Air Force Base, North Carolina as the Logistics Plans and Procurement Officer supporting special operations combat missions that include Just Cause (to include the capture of Manuel Noriega), Desert Shield/Desert Storm, and several classified operations.

After the Command and General Staff College, LTC Morris was assigned to Alaska where he served as the 6th Infantry Division EDRE/Force Modernization officer responsible for re-organizing the 6th Infantry Division to the Separate Infantry Brigade. He also served in Alaska as the 6th Infantry Division Operations Officer, Battalion Executive Officer for the 4th Battalion, 9th Infantry (Manchus), and the 1st Brigade, 6th Infantry Division (Light) Executive Officer. Following his assignment in Alaska, LTC Morris completed an assignment as Special Project Officer to the Assistant Secretary of Defense for Special Operations and Low Intensity Conflict, where he supported numerous international humanitarian organizations, programs, and operations that include the International War Crimes Tribunal for Rwanda and the former Yugoslavia. In addition, he was an author of the United Nations contingency support package concept. LTC Morris was selected as the battalion commander for 1st Battalion, 11th Infantry at Fort Benning, Georgia, and subsequently, served as the Chief of the Forced Entry Lab, Dismounted Battle Space Battle Lab, and Fort Benning, Georgia, where he refined the concept and configuration for Enroute Mission Planning. Most recently, because of his expertise in Enroute Mission Planning and Rehearsal, LTC Morris was personally selected by the Army Vice Chief of Staff to serve as an Army MEL-1 Fellow with the specific charter to study the requirements and develop a long-range plan for a Joint Enroute Mission Planning and Rehearsal System. In this capacity and in support of this Enroute Mission Planning research, LTC Morris conducted the first ever detailed Work Style and Work Style Under Stress study of Army Rapid deployment forces. LTC Morris also serves as a Subject Matter Expert for NGO/PVO civil-military interoperability for the Army Command and General Staff College. As a volunteer, he authored and facilitated the World Food Programs first-ever deliberate planning course and program.

In 1994, LTC Morris founded the non-profit organization, *Partners International Foundation*, a 501(C)(3) Public charity for which he currently serves as president. *Partners International Foundation* has no paid employees and current projects include raising funds to establish a Women and Children's wellness center in Rwanda for victims of the genocide, operating an eye clinic in Zimbabwe, and providing medical supplies to a women and children's hospital in Grenada. Programs in the United States include Human Rights training for international military officers and support to homeless shelters, battered women's shelters, Native American programs, and the disabled. The foundation also supports *The World Peace Club*, an Internet project run by children to promote understanding between nationalities. *Partners International* has close ties to the Columbus community through the Muscogee Rotary, where it supports several of the club's overseas programs and is seeking funding to support its *Minds Without Boarders* program to train teachers in special skills to increase the learning level of poor learners in disadvantaged communities. (*www.partners-international.org*)

LTC Morris' decorations include the Legion of Merit, the Bronze Star, the Defense Meritorious Service Medal, five awards of the Meritorious Service Medal, the Joint Service Commendation Medal with two bronze oak leaf clusters, the Army Commendation Medal, the Joint Service Achievement Medal, the Joint Meritorious Unit Award, the Army Achievement Medal with five oak leaf clusters, the Superior Volunteer Service Medal, Southwest Asia Service Medal with two bronze stars, the Armed Forces Expeditionary Medal, the Army Service Ribbon, the Overseas Service Ribbon with two bronze oak leaf clusters, the Southeast Asia Kuwait Liberation Medal, the Government of Kuwait Liberation Medal, the National Defense Service Medal, the Expert Infantryman's Badge, Master Parachutist Badge, and Ranger Tab.

Lieutenant Colonel Morris is married to the former Kim E. Etzler and they have two children: Katie, 14, and Robert John, 14 months.

Col. Jim Murphy

USMC Ret.
Analyst
Dynamics Research Corporation

Jim Murphy is a retired Marine colonel who has specialized in tactical command and control studies since leaving active duty in 1992. He worked initially as an after-action review (AAR) exercise analyst in the Eighth Army Battle Simulation Center in Korea. Subsequently, he assisted in the exercise design and execution portions of the first two Army STOW (Strategic Theater of War) experiment: STOW-Europe in 1994 and Prairie Warrior 95. In 1997, he became one of a number of persons who can claim to have written one of the drafts of Marine Corps Warfighting Publication (MCWP) 5-1, *Operational Planning.*

Joining DRC in October 1997, he served as the military functional member of an Army Research Laboratory (ARL) cognitive engineering team developing both process and cognitive models of the commander's decision-making process. In a related project, he was the lead analyst in developing prototype *behaviorally anchored rating scales* (BARS) for 17 commander-staff team proficiencies. He continues to support the Human Factors analysis team at ARL. He participates as a field data collector and post-experiment analyst in the continuing series of advanced warfighting experiments (AWE) supporting the development of the Army Battle Command System (ABCS).

He had a balanced mix of command and staff experience while on active duty and was a Joint Specialty Officer. He is a graduate of the US Military Academy and the US Army Command and General Staff College. He has a Master of Military Art and Science (MMAS) degree from CGSC and an MBA from Hofstra University.

Christopher K. Neff

Logistics Program Analyst
CINCPACFLT Logistics Office
US Pacific Fleet

Chris Neff has been serving as the principal logistics program analyst for the US Pacific Fleet since May 1999. Prior to this post, he was the principal Base Operating Support (BOS) program analyst for facilities and base support services throughout the Pacific Fleet Area of Responsibility from Nevada to the Indian Ocean.

Mr. Neff enlisted in the US Navy in 1969 and was subsequently selected for the Navy's Enlisted Scientific Education Program (NESEP), where he earned a Bachelor of Engineering Degree in Computer Science prior to assuming jobs as an Electronic Material Officer,and Supply Officer on USS Davidson and USS O'Callahan respectively. His 21 year career included assignments as Accounting Officer, Financial Management Officer, a financial systems project director, Fleet Budget Officer, and comptroller, on the staffs of the US Surface Force commander Pacific Fleet, Chief of Naval Operations, Navy Comptroller, Pacific Fleet Commander, and Commander Naval Logistics Command, Pacific.

He has been a regular lecturer at the Navy's Postgraduate school in the area of financial management and has taught graduate and undergraduate courses in financial and managerial accounting, as well as strategic management. He has a Masters Degree in Business Administration.

CDR Christopher D. Noble

Surface Warfare Analyst
US Navy

Commander Noble is the son of Dr. Charles and Anna Mary Noble. A native of Northeastern Oklahoma, he received his commission from the Officer Candidate School, Newport, Rhode Island, in the summer of 1980.

Commander Noble has completed six sea and two shore tours. He first served as a division officer on USS BARBEY FF-1088 and USS CHANDLER DDG-996. Then as a department head, he served tours as Engineer Officer on USS MCCLUSKY FFG-41 and as Damage Control Assistant on USS RANGER CV-61.

Additionally, he was the first Commanding Officer of USS GLADIATOR MCM-11. He commanded USS FLETCHER DD-992 from June of 99 until December of 00 completing an Arabian Gulf CVBG deployment. While at sea, he completed five major deployments that include Operations Earnest Will, Desert Shield, Desert Storm, MCM Euro 95, and Operation Southern Watch.

Ashore, Commander Noble has served in Washington as a deputy resources and requirements sponsor on the OPNAV staff in the Expeditionary Warfare Directorate. He also served as Special Assistant to the Director of the Commandants Warfighting Laboratory for the Hunter Warrior Battle experiment. Commander Noble is now the Surface Warfare Analyst in the Secretary of the Navy's Office of Program Appraisal.

Commander Noble's education includes both traditional and joint curricula. He holds a B.S. in Biology from the University of the State of New York and a M.S. in Weapons Systems from the Naval Postgraduate School in Monterey. He has completed joint professional education by attending the US Army's Senior War College in Carlisle and the Joint and Combined Warfighting course at the Armed Forces Staff College in Norfolk.

Among Commander Noble's awards are: Meritorious Service Medal (three awards), Navy Commendation Medal (two awards), Navy Achievement Medal, Navy Unit Citation, Armed Forces Expeditionary Medal, National Defense Medal, and Kuwait Liberation Medal.

Commander Noble is married to Dianne, daughter of Norman and Lene Piper of Sun City, California. They have three sons, Clint, Barret, and Travis.

Dr. Jens G. Pohl

Executive Director
Collaborative Agent Design Research Center
Professor of Architecture
California Polytechnic State University

Dr. Jens Pohl holds the positions of Professor of Architecture, Executive Director of the Collaborative Agent Design Research Center (CADRC), and Post-Graduate Studies Coordinator in the College of Architecture and Environmental Design, California Polytechnic State University (Cal Poly), San Luis Obispo, California, US.

Professor Pohl received his formal education in Australia with degrees in Architecture and Architectural Science: B.Arch. (University of Melbourne, 1965) M.Bdg.Sc. and Ph.D. (University of Sydney 1967 and 1970). He taught in the School of Building at the University of New South Wales in Sydney, Australia, until the end of 1972 and then left for the US where he was appointed to the position of Professor of Architecture at Cal Poly. Following several years of research and consulting activities in the areas of building-support services and information systems, Dr. Pohl's research focus today lies in the application of distributed artificial intelligence methodologies to decision-support systems in engineering design, logistical planning, and military command and control.

Under his direction, the CADRC at Cal Poly has over the past decade developed and implemented a number of distributed computing applications in which multiple computer-based and human agents collaborate in the solution of complex problems. Foremost among these are the ICDM (Integrated Cooperative Decision Model) and TIRAC (Toolkit for Information Representation and Agent Collaboration) frameworks which have been applied to engineering design (industry sponsorship: ICADS - 1986 to 1991), energy conservation (US Dept. of Energy sponsorship: AEDOT - 1992 to 1993), logistical planning (US Army (MTMC) sponsorship: ICODES - 1993 to present), military mission planning (US Marine Corps (MCWL) sponsorship: FEAT, FEAT4, and IMMACCS - 1994 to present), and facility management (US Navy (ONR) sponsorship: CIAT and SEAWAY- 1996 to present).

The Integrated Marine Multi-Agent Command and Control System (IMMACCS) was successfully field-tested as the command and control system of record during the Urban Warrior Advanced Warfighting Exercise (AWE) conducted by the Marine Corps Warfighting Laboratory (MCWL) in Central California (Monterey and Oakland) during the period March 11 to 18, 1999, and during a live fire Limited Objectives Exercise (LOE) held at Twentynine Palms, California, in March 2000. The Integrated Computerized Deployment System (ICODES) was designated by the US Department of Defense as the 'migration system' for ship loading in July 1995. ICODES 3 was released to the US Army in 1997, and ICODES 5 was released to the US Marine Corps and US Navy this year (2001).

Dr. Pohl is the author of two patents (US), several books, and more than 80 research papers. He is a Fellow of the International Institute for Advanced Studies in Systems Research and Cybernetics and was awarded an honorary doctorate by the Institute in August, 1998, during the InterSymp-98 conference held in Baden-Baden, Germany. Professor Pohl is a Fellow of the Royal Australian Institute of Architects, a Fellow of the Australian Institute of Building, a Member of the American Institute of Constructors, and a member of IEEE. He is a licensed architect in the states of New South Wales and Victoria, Australia.

Kym J. Pohl

Senior Software Engineer
Collaborative Agent Design Research Center
California Polytechnic State University

Kym Pohl is a Senior Software Engineer at the Cal Poly Collaborative Agent Design Research Center. In addition to providing technical consultation on a number of projects, Kym currently provides technical leadership for the SEAWAY and LOGGY maritime logistics project, the FCADS Command and Control System, and the ICDM project. Kym holds Bachelor of Science and Master of Science degrees in Computer Science and a Master of Science degree in Architecture. His research interests are in the application of agent-based decision-support theory.

Col. Anthony A. Wood

USMC (Ret.)
Director of Applied Research
Collaborative Agent Design Research Center
California Polytechnic State University

Colonel Anthony A. Wood joined the Collaborative Agent Design (CAD) Research Center at California Polytechnic State University in 1998 as Director of Applied Research. A Marine for over 30 years, including more than two years of combat duty, Colonel Wood joined the CAD Research Center following a distinguished career during which he was twice decorated with the Distinguished Service Medal, the nation's second highest, as well as the Legion of Merit, Bronze Star, and others. In the course of his service, he has been responsible for a number of unique conceptual and practical contributions to joint warfare, naval expeditionary warfare, and our military posture in the Pacific.

In 1968, he served his first tour in Vietnam as a platoon commander and then advisor to the Korean Marine Corps Blue Dragon Brigade. In his second tour in Vietnam in 1974-75, Captain Wood commanded a joint-contingent executing clandestine mission in Laos, Cambodia, and Vietnam. In January 1975, Maj General Homer Smith, USA, the Defense Attache in Saigon, had him transferred to the Defense Attache Office, where has was directed to secretly develop a plan for the evacuation of Saigon. Capt. Wood then executed that plan in April of 1975. Col. Wood has since served in a succession of infantry and reconnaisance command billets and several staff assignments.

As the principal author of the US Navy and Marine Corps “Maritime Prepositioning Concept”, he developed a detailed concept and then supervised the implementation of a national strategic response capability based on forward positioning three squadrons of specially configured climate controlled ships. Each of these squadrons contained prepackaged supplies and equipment sufficient to support a force of 15,000 Marines for thirty days.

While serving as Chief of Staff Marine Forces Pacific, Colonel Wood was dispatched to Russia in 1993. There, over a two-week period of negotiations, he successfully concluded a major tension reduction agreement and multi-year exercise program with the Russian General Staff, the Commander Russian Pacific Fleet in Vladivostok, and the Commander Russian Far East Military District in Kharbovsk. Designed to relax tensions and reduce the risk of nuclear incidents in the Pacific Theater, the agreement has since been extended.

Colonel Wood's last billet was as founding Director and Commanding Officer of the Marine Corps Warfighting Laboratory from 1995-1998. Unique in its concept-based approach as well as its projection of a very different and non-traditional post cold war future, the laboratory spear headed Marine experiments to recast military capabilities in a mold appropriate to emerging future requirements.

Col. Wood's decorations include the Distinguished Service Medal (multiple awards), the Legion of Merit, the Bronze Star with Combat V, the Meritorious Service Medal, the Joint Commendation Medal (multiple awards), and the Combat Action Ribbon (multiple awards). At the time of his retirement in June 1998, Colonel Wood was the only Colonel or Captain on active duty in any service to have been twice awarded the Distinguished Service Medal.

Michael Zang

Senior Software Engineer
Collaborative Agent Design Research Center
California Polytechnic State University

Mike Zang is a Senior Software Engineer at the Cal Poly Collaborative Agent Design Research Center. Mike currently provides technical leadership for the OTIS and SILS maritime logistics projects, the CIAT port management project, and the COACH project for providing repair assistance, as well as technical consultation on a number of other projects. Mike holds a dual Bachelor of Science degree in Electronic Engineering and Physics. He was a ROTC scholarship recipient and worked as an officer in the Army Reserves for 8 years. His research interests are in software system architecture and applied artificial intelligence.

Keynote Address

Mr. Andrew W. Marshall
Head, The Office of Net Assessment
US Department of Defense

Thank you very much for the overly generous introduction. What I wanted to talk with you about this morning is first, the importance of field experimentation, and second, to say a few words about the history of past military innovations and what made such efforts successful. I myself am not an expert in actually running field experiments. A number of you know much more than I do about actually running such events. So what I have to say is based primarily on history.

Over the years I have become interested in the history of periods of major change. Over a decade or so ago, when we first began to examine the possibility that we were living in a period where major change in warfare is likely or plausible, one of the things I did was to initiate a number of historical studies to gain some understanding of what actually happens during such periods. How does the change process occur, how long does it take, and particularly I wanted to gain some insight into past periods during which there were competing military organizations that more or less had the same technology and the same opportunities. In short, I wanted to understand why one organization did better than another.

Let me talk briefly about the period that we are in now. I think that there is a growing belief, certainly not everyone actually believes it, but a large portion of people do sense that we are living in a period of really major change. A period in which we are not just dealing with normal steady progress, but a period in which really disruptive change could take place. In the military area, we owe our current attention to the idea of revolution in military affairs to the military theorists in the Soviet Union. They began writing about this idea of periods of military revolution which the historians of more than forty years ago first raised. Periods, in the broad sweep of history, where really significant change in warfare takes place. Periods of perhaps a couple of decades or fifty years. While historians argue about the number of such periods, ranging from six to twelve since the 15th Century, they appear to be coming closer together, perhaps because many of these periods (although not all of them) are driven by technological change. In any case, that we have become self-aware that we may be in such a period of major change, we owe to the Russian military theatres too.

What is interesting about those periods and particularly some of the more recent ones, like the 1920s and 1930s, is that the more successful military organizations in these periods tend to be those that find the right operational concepts and create the right military units for experimenting with the use of the technologies that are available. It would therefore appear to follow that if you believe that you are in one of these periods of major change, then you are under an obligation to try to identify the most promising operational concepts and to establish what you think are the right new units to use in field experiments.

Because of this, I have come to believe that field experiments are tremendously important. People can go only so far with war games and conceptual analyses. In the first place the models of combat that we have are just not good enough. They do not capture the entire nature of the issues that are being investigated. The most poorly treated aspects of warfare happen to be those where the technology is currently changing most rapidly, i.e., the information related to technology, etc. In many cases the issues that need to be explored are very complex. Some of the most successful cases of major changes that have been looked at in detail (the US Navy's development of carrier air operations and the German development of the Panzer Division and armored warfare in the 1920s and 1930s) involved field experiments. Moreover, in the best of these cases the field experiments fed back important data to related war gaming efforts. They provided better notions of what the exchange rates will be in combat operations and served as a basis for calibration of the parameters in the models used in the wargames. In other words, while ideas and concepts come from the war games, the field experiments allowed the war games to improve. The result is a very important cycle of concept evaluation and testing that leads to success.

The other aspect that I believe is particularly interesting and important about field experiments is that they present opportunities for the people involved to learn the special skills that may be required to operate under new conditions. During periods of major change in the past, the new military specialists acquired the kind of knowledge that can only be obtained through active practice and hands-on experience. Furthermore, this knowledge can be passed onto other people only through working alongside the people who already have mastered those particular skills. Also, field experiments often generate hardware/or operational inventions that make the concept possible.

One of the cases that we and others have looked at most thoroughly is the development of naval air capabilities in the United States in the inter-war years. What we see is an initial emphasis on war gaming. Out of these came ideas that led to fleet exercises utilizing some ships as surrogates for aircraft carriers. Then the Langley came into service in December 1924, which allowed experiments in conducting flight operations. They wanted to change the way flight operations were being conducted. The British had carriers before the US Navy did and had adopted a process for operations that was too slow to allow the formation of large strike formations, which the war games had shown were the key to success. The US Navy changed the take off and landing process, invented the crash barrier and other things that were necessary to speed up these operations.

As with most human knowledge, people learn a great deal by doing things, testing new ideas, and so on. Another possibility for learning, which is not really a field experiment, is learning from real operations that allow people to try out things they have a requirement for. We would not be nearly as far along in areas such as communication systems and data systems, without the lessons learned during real operations. I believe that a specific case in point is the Unmanned Airborne Vehicle (UAV). We would not be nearly as far along in the use of UAVs if it had not been for the Bosnia and Kosovo operations which allowed the development of ways of using these devices and linking them together with other sea forces. I think that we often, however, do not fully use these opportunities for learning and do not capture all of the lessons that people have in fact learned.

Now let me go back and look at some of these examples to draw lessons as to what history suggests makes for success. I am talking of success being something like the development of aircraft carrier operations or the development of the Panzer Division, and all of the operational skills and everything that went with them. Full success requires not only the adaptation of devices supplied by available or feasible technology, but also the formulation of new concepts of operation and a new set of skills that go with the new way of operating. In this arena, the officer corps is the central player. In both of the previously mentioned examples of successful change there was a subsection of the officer corps who became convinced that change was necessary and feasible. They were people who saw some new way of operating, or some new kind of unit, as being particularly valuable. And they were able to form new units, to conduct experiments and to coeval equipment, operational practices, organizations and skills.

This process goes far beyond isolated experiments. I do not believe that successful change can come from isolated experiments, in the way that we have to some extent operated recently. Historically, it has been far more promising to allow a group of officers to go off and create a new unit that stays in existence and continuously evolves over a period of three or four years. This can influence the design of future equipment, the evolution of new concepts of operation, small incremental inventions like the crash barrier net, and over time potentially still greater changes. The German case is very instructive in that, in the first design of the Panzer Division they had about 600 tanks. The final design had only about 225 tanks, because they found in their field experiments that they could not do what they wanted to do with the larger number of tanks. The basic goal and concept was one of punching through enemy lines and operating deep in his rear areas.. They found that to achieve this goal they had to have a lot more infantry, a lot more transporting fuel and other things in order to achieve this decisive punch into the rear area. The original design was far too tank heavy, and over the course of the three or four years that they had before the war, the design evolved very quickly and was greatly improved.

Something similar happened in the aircraft carrier case. This suggests to me that if at all possible you want to have some small units that continually evolve. Some of them will be failures. In the German case, when they began to re-arm the army had seven new kinds of units, only four of which survived. So in some way, and I am not sure what the right word for this is, we should use a prototype unit that evolves and develops rather than a single experiment. However, in order to be able to implement this approach to experimentation there needs to emerge within the officer corps at least a small cluster of people who believe in some idea, some new way of fighting or some new operational concepts that they wish to pursue. It concerns me that we seldom provide the opportunity and enough support for such prototypes. Our tendency is to conduct experiments and then disband the unit. I suppose ideally, the younger officers in all of the services ought to be allowed to form some prototype units that further the accomplishment of the key tools of their services. These groups would formulate some competing ideas about new kinds of units or new operational approaches, and then some more senior group would select what they judge to be the two or three best ideas and allow them to proceed.

One of our current problems obviously is that we have a high operational tempo. People are very busy. One of the wonderful things about the 1920s and 1930s was that none of the military services had any money, but they had plenty of time. US Navy ships went out to sea a couple of days a week and there was one large fleet exercise a year, so there was time to experiment and think. Today we have a military that has almost no leisure time for those kinds of activities.

Another ingredient that I believe makes for success is the existence of some original concept that underlies the new design and what we do with it. It was certainly true in the case of the Panzer Division. What made the German efforts more successful was that they had this concept of punching a hole and getting deep into the rear of the enemy lines. This led to the design of tanks that were lighter, faster, and had a longer range than had been previously contemplated. Both we and the French initially went down the line to design the tank to support the infantry. In fact, the US Congress passed a law at one point that imposed a speed limit on the tank so that it could not outrun the infantry. In other words, having the right concept is very, very important. In the case of the aircraft carriers the war games had suggested that what you wanted to do was to get as many aircraft in the air as you could, at one time. The important American invention in some sense was to take that notion seriously and to dramatically change the whole way of staging flight operations so that this objective could be realized. This was one of the features that appealed to me about the Hunter Warrior experiment undertaken by the Marine Corps Warfighting Laboratory a few years ago. It was concept-based, and not just an experiment to see whether we liked some new devices or what computers can do for us. Rather it was a concept where they improvised some new devices, and the experiment was designed to determine the feasibility of the concept and the best way of implementing the required operational support.

I do not have very much more to say than that. In summary, I believe that field experiments are tremendously important. I do not believe that human beings solve problems or effectively question existing solutions without experimentation. To acquire new skills you have to go out and do it. History suggests that the best way of doing this is either through some systematic series of experiments, field experiments, or the establishment of a unit with a concept-based notion about some new way of operating that stays in existence and evolves over the course of at least three to five years. The best thing that could happen in our military would be somehow to move in the direction of more field experimentation, more prototype units evolving over time.

Military Experimentation: Considerations and Applications

Anthony Wood (Col. USMC Ret.), Director of Applied Research
Collaborative Agent Design Research Center
Cal Poly, San Luis Obispo, California

Good morning! I'm going to follow Mr. Andy Marshall with personal observations collected over more than 20 years of military experimentation. My view is a composite one: that of a young officer involved in experimentation; that of a staff officer involved in developing Maritime Prepositioning through a process of practical experimentation; as the Officer In Charge of "Hunter Warrior", the Marine Corps' Advanced Warfighting Experiment (AWE) during the early Sea Dragon series; and, finally, as the founder and first Commanding Officer of the Marine Corps Warfighting Laboratory. As I discuss experimentation as a road to the future, I'll try to offer frank observations so that others might avoid some of the difficulties we faced.

We have well-developed processes in the United States military for everything except identifying and dealing with major change. Allow me to relate a short tale of success at implementing change, and the "rewards" that followed. In 1982, a group of staff NCOs and officers, composing the staff of the Sixth Marine Amphibious Brigade, boarded a very rusty old amphibious assault ship for a three day voyage to Guantanamo Bay, Cuba. During the course of that sail, staff and officers were organized into four syndicates. Each syndicate was responsible for developing, briefing, and then defending an approach to part of an experimental concept called Maritime Prepositioning which was then under development by the Navy and Marine Corps. On reaching the base at Gitmo the combined results of the syndicates would provide the basis for four days and nights of trial and error leading to a written SOP.

When we docked at Gitmo we had a 30 page paper. It proposed a series of measures and organizational changes for dramatically cutting the strategic response time for a powerful brigade. Essentially it laid out a proposal for forward afloat positioning of brigade supplies and equipment on specially designed ships that would be complemented by a fly echelon and link-up for combat. Sound like a *concept* to act as the experimental basis? We had an amphibious ship and one example of each piece of major equipment in the Marine Corps. Sound like the *use of surrogates* for experimentation? We had designed a scenario and command post exercise to be executed in Cuba. Sound like an *experimentation plan*? And, we had several TRS-80 Radio Shack computers sets side-by-side with three men behind them to move the disks and track equipment and timing in transit after offload evolution at the docks. This of course was an early primitive effort at *documentation* and *analysis*.

The outcome less than three months later was the Maritime Prepositioning Progam SOP, a document that has undergone remarkably few changes since first drafted. Subsequently, other findings from the early experiments found their way into special capabilities that would be reflected in the design of the Prepositioning ships. And a whole set of further "findings" ("experiments" today) shaped what has now become a polished Marine Corps capability: the formation and execution of a task organized fly-in echelon (FIE) which would link up with the prepositioned supplies and equipment.

In my opening I stated that I would tell this tale and then mention the “rewards” that followed. Shortly after the Secretary of Defense arrived at our base to complement the Brigade on two years of effort, the Brigade’s Commanding General, then BGen Robert F. Milligan and his planner then LtCol Anthony A. Wood were relieved and transferred. Maritime Prepositioning was regarded as a strategic gem by DoD (US Department of Defense), but the pace of change was far too fast for digestion by some within the Corps. That would only come with time. The thought I would leave with you is the importance of carefully preparing the ground for introducing innovation. *If innovations are to be accepted, evolution is preferable to revolution.*

My second observation is to deal with reality rather than tilt at windmills. Build a successful experimentation program that compliments, not competes with the acquisition and program goliaths that are already in place. Now I’ll admit this has not always been my attitude, but it has become my attitude (after a certain amount of soul searching), because I think it is very important that experimentation proceed. If it is to proceed, we must preserve dreams and observe practicalities.

With those as introductory framing remarks, my remaining comments address the key components of the experimental process, the guiding vision, how the vision is used, the men and women who do experimentation, leading them, the leader’s responsibilities, and closing comments on the experimental process itself.

The vision should be a formal document. Regard it as a living document that will change as you go along. I am certain that I won't say it as well as Andy Marshall did, but the vision must be derived from an initial analysis of the world that lies ahead. It must reflect the social, political, economic, and technological frame within which military force will be employed. In a real sense, the military capabilities that will be required are *derivative* from this larger frame. I would suggest to you that the vision document always begins with this careful analysis of what lies ahead, then looks at the nation, mixes in likely service roles and missions, and then current service concepts and responsibilities. If we have done a good job, *the vision document will suggest a set of military concepts and capabilities necessary to support the nation’s future interests.*

With that said, just what roles does the vision play? First of all, it is the compass for experimentation. It sets the course. Critically, it gives you the basis from which to extract, first concepts, and then capabilities for experimenting. At once it acts as a “backboard” against which to bounce proposals and ideas as well as a “scoreboard” for assessment. Ideas will flood you in this business. The question is, do they support and are they consistent with the *vision*? Resources are finite. Good ideas also need to be ideas that are appropriate to the experimental mission of the service.

Vision also gives you one other very important capability. When you go before Congress or go before other audiences, the vision statement gives you the clear structure with which to trace the logic and potential contribution of everything you're doing from the experiments in the field to future war fighting capabilities. In other words, it gives you the logic that is critical to defending your position and securing further funding.

This isn't about bumper stickers. Everybody has a vision statement in industry today, and they're rarely useful as a guide for anyone in the trenches. The vision statement needs to be very carefully wrought, *and it should be uniquely the responsibility of the commander*. While he may draw in other smart people as contributors, the final product is his responsibility. Further, the drafting isn't a democratic process. While committees are terrific at providing consensus, *a good vision statement almost never will gain consensus*. By its very nature it is projecting a set of capabilities that don't exist but are needed. It's projecting a sense of strategy that may need to be adopted but has not yet been tested. Consensus is not the goal of the vision document. *The vision document is a guide to experimentation and the future, not a justification for the current force.*

Approving a service vision as a basis for experimenting introduces the first of several frictions that characterize military experimentation. . There is no pat answer to gaining approval of the vision. However, I will say that after watching labs in the Army, the Navy, the Air Force, and the Marine Corps, and talking to many men and women involved in the process, we all could agree on one thing: *"The higher the top cover, the better"*. Said differently, the more controversial the program, the more important it is that you have top level approval of the vision document that guides it.

Mr. Marshall suggested that it would be desirable to have a strong group of younger officers working as sort of full time "red team". I agree that this could be invaluable. Implementing this "red team" proposal requires that the institution itself, or at least a large portion of its top leadership, provide approval and shield them from the inevitable pressures to conform which will emerge. Unless this cover is extended, experimentation may become little more than demonstration or justification of existing capabilities.

Experimental organizations need to combine the ability to generate good ideas with the need for experience and judgement. Any experimental organization must provide a channel for surfacing good ideas. The channel must be a clear one because good ideas rarely survive a long journey through hierarchy (<u>very</u> rarely.) The young guys are unencumbered with tradition or with position, they <u>often</u> have terrific ideas, and given a conducive atmosphere, they will voice them. The more senior members of an experimental organization have two things that are also invaluable: experience; and, judgement. These are important qualities for reviewing and then selecting good ideas for experimentation. In any case, if at all possible, *build the organization by identifying and recruiting individual talent* whether junior or senior. Experimental organizations are not cast from a standard mold; it is a great mistake to establish a staff and a plant before the vision and mission are defined.

I have a theory that the size of experimental bureaucracies and the size of their budgets is inversely proportional to output. The danger, of course, is that we will manage the large and demanding hierarchy at the expense of momentum and experimental substance. Suddenly, personnel management and the management of the organization supplant what we're really here to do. Experiments don't do well in a bureaucratic climate. Rather, they thrive on a sense of commitment and purpose, a great deal of talent, and a lot of energy. This doesn't mean that large bureaucracies can't put on experiments. But, to gain the quality that comes as a result of the courage to question established views, I believe that you must build teams within a large bureaucracy and give them the independence to proceed. That word “independence” is critical – and also the *top cover* that preserves it and allows the teams to exercise it.

Nothing, absolutely nothing, is as important as the selection of the men and women who will staff the experimental organization. And nothing is more important after their selection than treating them with the respect which their contributions and their energies deserve. The acquisition community is not the model. The reason is simple: contracted talent will rarely suggest the unconventional or the disruptive. Instead we need to draw on the talent of retired military officers by making far greater use of the IPA route and give them the authority and independence that will garner results. They are the critical piece that provides discipline and judgement and a certain independent sense of good ideas. If they are treated with respect and given a challenge, then we can recruit men and women of excellence who are retiring and move them into our experimental organizations. There, along side of Marshall’s young “red teamers” we can take advantage of the full range of talent at our disposal.

Balance. This is the age old question of enough but not too much. If good ideas are to rise through the hierarchy, you need to carefully balance creating enough internal freedom to let them rise and *just enough process* to inject appropriate resources and discipline. This balance is critical and it often leads to criticism of the experimental organization. Why? Because freedom to speak out may foster the notion that the organization is “messy”. Another phrase which is sometimes used to describe labs is "not very military" and the label you may hear with regard to outspoken staff officers is "loose cannons." In the military we are a fairly conservative group of men and women and the label "loose cannon" is a very negative one. Once entered into a fitness report it is death. The responsibility to strike a balance between a free flow of ideas (perhaps including some from “loose cannons”) while injecting necessary process rests with the commander. It is a balance that he will have to continuously adjust – and doing it well may involve acceptance of criticism from his peers and his seniors.

I'm going to spend a little while on the functional role of the vision document because, if carefully crafted, it can lead us from broad <u>concepts</u> to the identification of key enabling capabilities. These key <u>capabilities</u> can then be further refined to provide the supporting <u>functions</u> that make up each capability. Once functions have been identified, experiments can be designed in which functions are grouped to evaluate the potential war fighting contribution of one or more of the key capabilities. The bad news here is that in my experience one man in five or six is able to read even a well-crafted vision document and extract from that document the capabilities that are necessary to make a proposed operational concept reality. This process is the heart of experimentation. A well-written prescient vision document presents a coherent description of the future environment and the concepts with which we expect to fight. Extracting key capabilities from it is the next critical step in order to build the experiments. Performing this extraction demands a group of men with imagination and a great deal of experience. This is one of several times senior retired officers make a major contribution. Their experience enables them to assess the required underpinnings behind the broad concepts, and imagination and breadth allow them to define these into key capabilities. In my experience, perhaps three or four out of a staff of 40 or 50 have this unique and vital insight.

So let's have a quick look at the logic of how we get from concepts in the vision document to capabilities and finally supporting functions suitable for experiments. I'm going to post a statement on the screen that may well appear in a vision document today in any of the services. ***"A force that can combine its information superiority with an adaptive command and control capability will be able to dynamically adjust its decision-to-action loop to stay well ahead of its opponent's."*** My guess is we probably could extract a minimum of six or eight or even 10 key capabilities from this visionary goal. I have extracted one that you might consider an important derived capability: *"The capability for an adaptive command and control system to continuously monitor the situation and assist in dynamically re-allocating reconnaissance, surveillance, and target acquisition assets."* There's a whole bunch of subordinate functions tied up in this broad capability statement that support achieving *useful information superiority* (information superiority means nothing if it isn't useful.) The trick is, further breaking the capability functions that men and women can examine and incorporate into the design for an experiment.

We've examined a concept in the vision. We have seen how we might derive the 10 or 12 key capabilities that make up the broad concept, and how each of these can be broken down into functions. Now the commander and his staff can review the proposed experimental program, identify a place for the new proposed experiment and move to questions of priority for resources and implementation. What I've tried to do in this short example is to present the notion of the key role that the vision document plays in providing a basis for presenting concepts, deriving capabilities, and identifying the supporting functions composing each capability. Once those functions have been identified experiments can be designed.

I didn't know Mr. Marshall was going to mention the use of surrogates in experiments, but I'm delighted that he did. Surrogates play an important role. Remember my little tale at the start of the talk concerning the development of Maritime Prepositioning? We certainly didn't call them surrogates just as we didn't call the research and test period an experiment, but that old amphibious ship was the "surrogate" for later development of the TAK maritime prepositioning ships. History has many examples of the use of surrogates. Prior to WWII, the Germans used old cars and trucks as surrogates for tanks during early development of Blitzkrieg tactics. They didn't need actual tanks to explore the concepts (nor did they have them). Instead, to determine effective formations and tactics, they experimented with the Blitzkrieg concept through use of surrogates -- cars and trucks in formation running around, linked by primitive communication means.

Using surrogates has several advantages in contemporary experimentation. First, surrogates can speed the process of experimentation (don't wait for the real item). Second, they can drastically reduce the cost. Finally, surrogates can keep you from adopting a particular technology at the outset. Committing prematurely to a particular technological approach locks experiments into a single direction. You have to be very, very sensitive to this danger. Many technologies are self-fulfilling prophecies. If you select a particular technology at the outset for the experiment, you may well be dictating the result *a priori*.

A well-planned and well-executed analysis and data gathering plan is one of the commander's principal responsibilities. Let me say that again. A well-planned and well-executed analysis and data gathering plan is one of the commander's principal responsibilities. Why? Isn't this a technical area best left to "green eye shade" types? No! In the end, all the effort that his gone into the experiment comes down to results. Those all-important results are going to be viewed through the lens of the analysis and data gathering plan. That plan must support the experimental mission. It must be specifically tailored to identify and evaluate the capabilities extracted from the vision. It must directly link means and ends in a clear fashion that employs credible MOE(s). When all is said and done, nothing receives more attention than the analysis. In my view you cannot be too careful. Demand the best in terms of analysts and establish a long term relationship that will ensure more analytical talent when it is needed. But, the adequacy of this plan is one of the commander's primary responsibilities.

If the analyst is important, the design of the experiment is equally so. Men who can design experiments are difficult to find. If you were a division commander, you would be incredibly careful concerning who was selected as your operations officer. And, if in fact that operations officer wasn't your pick, you'd make damn sure his assistant was the finest you could find. In experimentation, the head of experimental design is just that important. The recipe? One very, very talented guy who can clearly see the purpose of the experiment, relate goals to resources, understand the concept, evaluate the analysis and data gathering plan (and integrate it in the design), and then pull it all together with an experimental support and preparation plan. Sound like a tall order? It is. And then, of course, after you've picked a good guy and after you have placed your trust in him, check, check, check.

A word on presentation. More often than not experiments can be boring for the outside observer. I've heard it said that experiments are about as exciting as watching crab grass grow. For this reason, as well as the fact that they may occur at different sites over an extended period, *experiments have to be presented.* Not only are they often boring, *an experiment may not even be understandable without a presentation plan*. The presentation plan enables the experimental staff to explain what is actually going on and why you're doing it. The presentation plan also contributes to visibility and credibility and thus to securing future resources and support. As an example, there were nine general officers assigned by the Commandant of the Marine Corps to observe Hunter Warrior (Am I correct on that one?) -- nine general officers assigned as observers and evaluators for one experiment. But it was an important experiment. We had to do a very careful presentation plan. The experiment covered five different sites over a 3300 square mile battlefield and at sea. The presentation plan included a helicopter transport scheme to move guests and observers. It required a very carefully constructed information flow just so they would understand what the experiment was, what was going on, what the concepts under evaluation were, and how we were proceeding? And, it helped manage the crowd. In short, I would suggest that credibility requires that you be able to show and explain what you're doing and, at the same time, keep those who are observing from affecting the experiment. The tool is the presentation plan.

No one will be more sensitive to the publication of the final experimental results than your own staff. No one. How you as a commander present these results will surely have a major impact on every experiment that follows. If, under outside pressure, you tell a victorious experimental team that the game didn't count, that it's been called, you will only have to do it once. You only have to politically filter the results of an experiment once to convince your staff that it's not worth it to go out on a limb – and good experimentation requires that they go out on a limb. I'm aware of the conflicting pressures which tug at the experimental commander when final results call into question some important aspect of the status quo. However, there is a heavy responsibility to the parent service, to the experimental mission, and to your staff to accurately portray your findings. As Mr. Marshall implied earlier, in this business *courage really does count*.

At this point I'd like to briefly comment on exercises and experiments. These two activities are very different. Resource pressures are pushing us to include experimentation within exercises. And there may be no way to avoid that entirely. However, we owe it to ourselves to proceed with a clear understanding of the differences between experiments and exercises.

Critically, the experiment must be structured and conducted in such a fashion that failure is one possibility. The hypothesis can turn out not to be provable, otherwise why experiment? If this is not the case, if so-called experiments do not admit of the possibility of failure, then you're demonstrating or you're justifying, or you're camouflaging, but you're not experimenting.

The second major difference between experiments and exercises is the end purpose of each. The operating forces go to the field to polish current capabilities and ensure war fighting readiness. Their responsibility is to defend today. Nothing can get in the way of that, and nothing should. Furthermore, as Mr. Marshall alluded to earlier, the operating forces are practicing team work and improvisation. Exercises strengthen and polish the ability to improvise and interoperate. However this powerful commitment, to accomplish the mission and improvise as necessary to do it, can convert an experiment into a demonstration with positive results a foregone conclusions.

So there are several good reasons to be very careful about how we combine exercises and experiments. I've given up saying you can't do it (which I used to say), because the fact of the matter is, that resources today probably aren't going to allow us the luxury of separate venues. Further, there are many small experiments that in spite of their small scale are enormously useful and can be included under a larger exercise umbrella.

There are other practical considerations that arise when mixing experiments with exercises. Chief among these are the differing time horizons of each. A few years ago, I was briefing one of the CINCs and I was watching his face redden and temper rise as we tried to persuade him that he should support a major experiment. About halfway through the discussion, I suddenly realized that I was proposing an experiment whose outcomes would impact a time horizon which was five, six or seven years out. At the same time he was concerned with the capabilities which would be available to his forces across a huge theater for the next 24 months. The lesson is clear – keep a close eye on time horizons. Be careful when asking men whose responsibility is <u>now</u> to combine experiments whose impacts may be seven years out. Or if you are going to have to do it, tie it back to their responsibilities today.

The horizon issue also applies to mixing experiments and exercises within our divisions, wings, and fleets. As stated the responsibility of these commanders is the employment of the operating forces <u>now</u>. If we're going to ask them to host experimentation, then we should ask them to host experimentation that is appropriate, that fits into their exercises, and that in fact is likely to complement their capabilities in the fairly short term. And there will be periods during which experimentation will be focused on very short term enhancements. It's like a pendulum. Sometimes experimentation will have aggressive periods where we'll tackle very controversial future concepts and capabilities, and those will frequently be followed by more conservative periods during which we will focus on much more near term enhancements. It differs, service by service. But the fact is, both periods can contribute to identifying and refining war fighting capabilities.

At any rate, when we talk about experimenting within an exercise we are going to have to be careful that we don't drink our own bath water. It's very easy to do. Clearly, if well planned, experiments can be carried out within a large exercise without being negatively influenced. However, while our commitment to accomplishing the mission and improvising as necessary is a huge plus in maintaining current readiness, it can be just as big a detractor and unduly bend the results of experiments. Finally, remember that experiments fail. When was the last time you heard a senior commander announce failure?

Leading experimental organizations is tough. On one hand there is a responsibility to support and protect your staff and shield them from the pressures of acquisition, from service controversy, and from the knee-jerk reactions of those blindly committed to preserving the status quo. Equally, the experimental commander must retain the trust and support of the senior leadership or the program will be terminated. It's the commander's job to achieve balance, and it may not always be career enhancing. Coming to grips with this issue and having the services accept this will depend on very high level recognition of the importance of military experimentation. It will also depend on establishing a tradition that the general officers placed in charge of experimentation are in fact "between two worlds" and that their primary responsibility is to explore the capabilities we may need for the future. We should also strive to establish a widespread understanding that these experimental leaders are reasonable and very wise men as they direct this exploration. Believe me, they're going to have to be very wise men because as Mr. Marshall remarked, innovators have not traditionally been rewarded.

I'll close these personal remarks on experimentation, experimenters, and their processes with the comment that they are just that – personal remarks based on experience stretching back over more than 20 years of military experimentation. I hope my thoughts have complemented what Andy Marshall had to say, and I hope that they will prove useful to those engaged in military experimentation today.

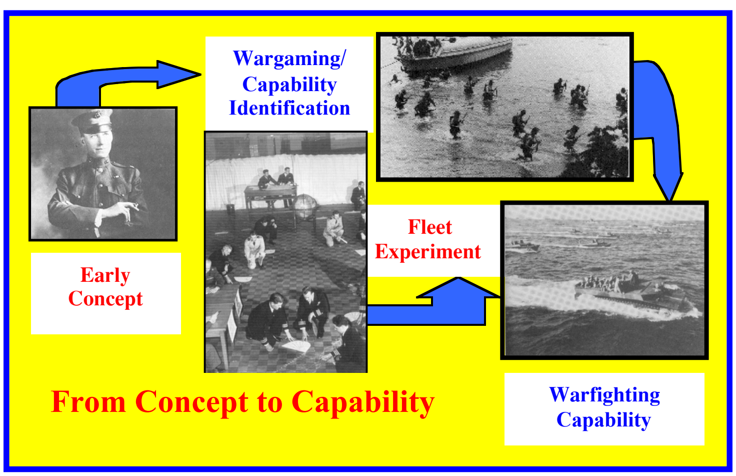
EXPERIMENTATION AS A COMPASS FOR THE FUTURE

By Colonel James A. Lasswell, USMC (Ret.)

Divining the future is hard. There are no reliable crystal balls in the Pentagon any more than there are on Wall Street. The military attempts to chart its future course through the use of such vehicles as White Paper *vision statements* and *future concepts* of how they perceived the military should respond to the future threat in order to carry out the National Security Strategy. In some cases, these future concepts are simply product improvements of current military objectives. However, at other times, the vision of the future requires a major change of direction – a transformation – that require a major departure from current *legacy* capabilities in order to either meet new challenges or to take advantage of new technological opportunities.

Experimenting with future systems present a major challenge because future technologies are by definition beyond the current state-of-the-art for current equipment. The situation is made harder if the new technologies offer the opportunity to implement new organizations, tactics, techniques and procedures – or even the development of personnel with different skill sets to operate – than current operational forces. In these cases, the only option may be to first wargame the concept and then when the capabilities are adequately defined attempt to conduct concept-based experimentation using surrogate technologies that approximate the future technologies sufficiently to permit operational assessment of the new concept.

This process has been used for over a century in the U.S. Naval Service. Wargaming at the Naval War College predates the turn of the century and was particularly influential during the interwar years in the development of fleet tactics for carrier and amphibious operations. Wargames can lead to experiments with surrogate technologies such as the landings on the Island of Culebra during the 1920s using small boats to simulate more advanced landing craft as an example. By the first World War II amphibious assault against Tarawa in 1943, the launches had given way to the Higgins boat, tracked assault amphibian vehicles, and a Fleet Marine Force organized and equipped to conduct amphibious assaults.



In the case of the amphibious assault, the capability took over 20 years from initial wargaming through initial experimentation in fleet exercises using surrogate systems, to the refinement of the concept into an actual warfighting capability. Arguably, one of the most difficult stages in this development is the transition of a concept into viable and meaningful concept-based experimentation using first surrogates and then candidate prototype technologies.

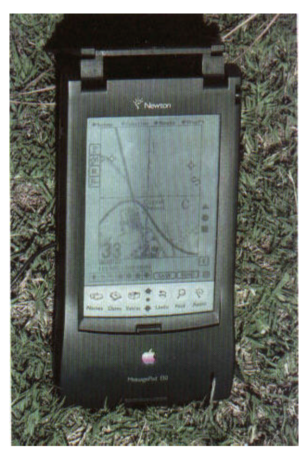
Even thought the Marine Corps Warfighting Laboratory is only about five years old, there have already been three examples of how a revolutionary concept has progressed from idea, to a wargamed capability, to a concept-based experiment with a surrogate, to more comprehensive experimentation with a prototype until they are now sufficiently defined that it can be evaluated for acquisition. Each in its own way provides an example of a different use of a surrogate technology in concept-based experimentation to establish the direction for future warfighting capabilities.

Concept Exploration – Defining the Potential of a Digital Battlefield

The initial experiment of the Marine Corps Warfighting Laboratory was the *Hunter Warrior* Experiment conducted during March 1997. This seminal Marine Corps experiment into the potential impact of technology generally associated with *Joint Vision 2010* when applied to the capabilities of a typical naval task force comprised of a future Carrier Battle Group and Amphibious Ready Group with embarked Marine Expeditionary Unit.

The centerpiece of the experiment was the use of a surrogate communications architecture that approximated the kind of digital network envisioned in the future supporting a form of Common Tactical Picture available in near real time at any location on the battlefield. The hub of the architecture was the Experimental Command and Control Center (ECOC).

The concept was based on a *vision* of the future battlefield in which information is digitally shared throughout the battlespace. Commanders at all levels could draw information from shared information data bases – similar in concept to the Joint Forces Command concept of a *Common Relevant Operational Picture* -- as required to provide situational awareness and to support their command and coordination requirements. Information would neither funnel up nor down a chain of command focused on filtering and interpreting information. Instead, information would be available near simultaneously to all echelons of command both on and off the battlefield.



The *Hunter Warrior* ECOC was intended to explore the implications of such a system on both staff organization and the types of decision-making systems that would permit distributing command and control functions within the battlespace. Most notably, the ECOC was intended to integrate the functions of the Landing Force Operations Center (LFOC) and the Tactical Logistics Group (TacLog) with Navy command and control functions such as the Supporting Arms Coordination Center (SACC) and Tactical Air Operations Center (TACC). Located at Camp Pendleton – as a surrogate for an amphibious command ship – the ECOC was connected by landlines and tower relays to tactical units on the ground at 29 Palms California over 150 miles away.

The landlines and towers were a key part of a surrogate communications architecture approximating future envisioned over-the-horizon, wide band wireless communications. At the other end of the architecture were Marine squads equipped with Apple Newton palm-top computers with embedded Trimble GPS cards that automatically established the location of the sending unit whenever it transmitted.The *Hunter Warrior* ECOC was originally intended to be a shipboard node of a network centric approach to organizing the future littoral battlefield around digital information. It was to be one of multiple nodes – not the hub – for decision making within the naval task force during littoral operations. In the concept, similar ECOCs would be located on the various ships of the Amphibious Ready Group and the supporting Carrier Battle Group, and ashore in mobile operations centers of the landing force

The Marine Corps Warfighting Laboratory developed a concept for a cellular staff organization to use the ECOC. The Staff was organized around functions. Fighting the current battle was the Engagement Coordination Cell (or section) that inherently combined all aspects of engagement – lethal fires, non-lethal fires, maneuver, psychological operations, etc. – into a single staff function.

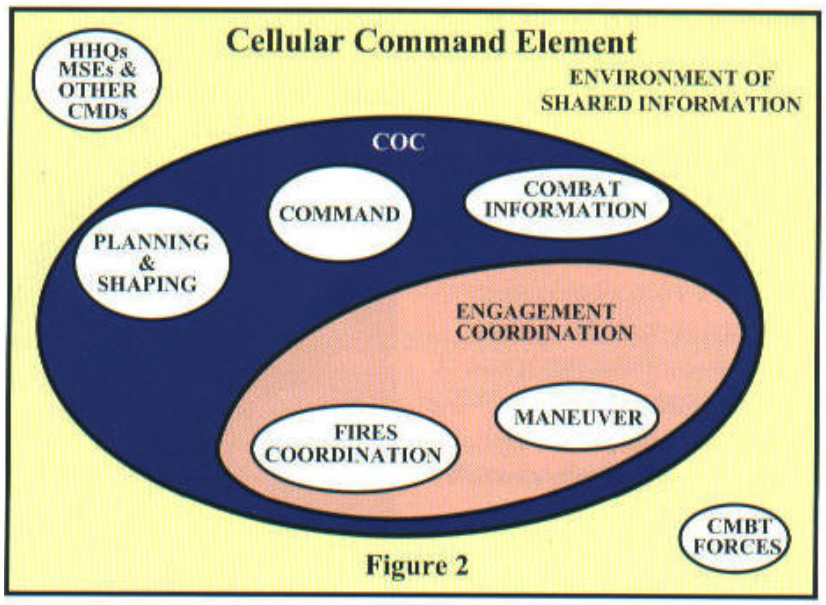


Figure 2

The concept of the Engagement Coordination Cell was not dissimilar to that of the Effects Based Operations Cell currently under review by Joint Forces Command. Supporting the Engagement Coordination Cell was a Planning and Shaping Cell – similar to a Future Operations and Future Plans organization in function – and a Combat Information Cell that performed an information management function. Notably, there was no intelligence fusion function. The experimental concept assumed that information technology would permit distribution of operationally critical intelligence information throughout the staff simultaneously to those individuals who needed it. A nascent intelligence fusion function was performed within the combat information cell and by a *red team* that provided an independent interpretation of the battle to the *battle captain* based on the perceived effects of events upon the enemy.

However, time and resources limited the development of the *Hunter Warrior* C2 architecture to a single ECOC and the concept for experimentation during the AWE to that of funneling all available information to a single centralized decision making node within the ECOC. Although spectacularly successful in some aspects, centralization during the experiment led to a focus in subsequent ECOC development into improving the decision-making capability of the ECOC rather than the exploration of the impact of shared information within a network centric approach.

The *Hunter Warrior* ECOC demonstrated the value of electronic displays of information within an ECOC. However, the *Hunter Warrior* ECOC did not have an integrated C2 system. Instead, it was a collection of stand-alone legacy systems that were used in the Advanced Warfighting Experiment with various prototype systems such as *xBAIT* and the *3-Dimensional Workbench* (for visually displaying information) and *FEAT4* (for intelligent agent manipulation of data bases) that were on display but not actually used in the conduct of the experiment.

The *Hunter Warrior* ECOC demonstrated how dramatically more capable a future command element might be able to command and coordinate forces on a widely dispersed future battlefield provided it developed the ability to automate the dissemination and display of the data pouring into the ECOC through the use of computer assisted decision support systems. In the Hunter Warrior ECOC all information was essentially distributed in near real time to every station within the staff due as text messages. Only the electronic map was updated automatically to show new position reports of both friendly units and enemy sightings. In spite of these limitations, the amount of information available within the staff and the lack of a vertical chain of command for the dissemination of information, led to significant reassessments as to the significance of automated decision support systems to help manage the information that an all- digital communications architecture can potentially provide.

The *Urban Warrior* ECOC developed for the *Urban Warrior* experiment in March of 1999, was a dramatic product improvement over that of the *Hunter Warrior* ECOC. The *Urban Warrior* ECOC was a dramatic change from that of the previous experiment in that it incorporated *intelligent computer agent* driven decision support systems. It was built around a prototype *Integrated Marine Multi-Agent Command and Control System* that was designed to employ computer agents in a variety of roles to aid in near-real time decision making. Agent functionality provided similar *racking and stacking of information* capabilities that currently requires a host Marines with pen and paper – and grease pencils on overlays -- to accomplish. The approach was to use intelligent agents to make information more usable by decision makers rather than as a substitute for a Marine in the decision making loop. Agents provided limited support to distribution of information throughout the network – down to the squad level in some cases using a computer end user terminal – but fundamentally remained focused on providing decision support to the ECOC staff.

During the June 2001 *Kernal Blitz (Experimental)*, the Marine Corps Warfighting Laboratory and the Extended Littoral Battlespace Advanced Concepts Technology Demonstration Program

Office conducted the third major experiment involving the ECOC. For this experiment, the ECOC is a state-of-the-shelf, high technology command center built from the bottom-up within an old magazine of the USS *Coronado.* Instead of surrogate terrestrial communications architecture, the ELB ACTD employed prototype systems that could eventually be employed in UAVs to serve as airborne relays for wideband secure wireless communications.

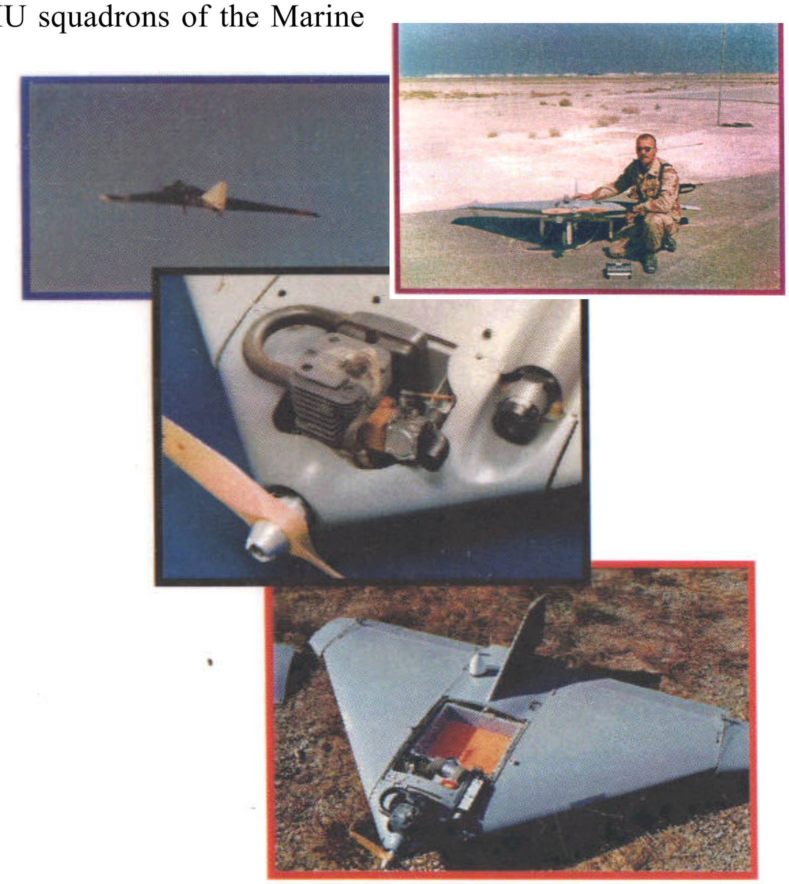
This new ECOC is several technical generations and a considerable conceptual departure from the original idea of an ECOC that was developed prior to the *Hunter Warrior* Advanced Warfighting Experiment Often lost in the focus on the information technology of the ECOC is its original operational concept.

The *Capable Warrior* ECOC used during *Kernal Blitz (Experimental)* is a product improved *Urban Warrior* ECOC that progressed primarily in its ability to incorporate legacy C2 systems with a wide band communications system. However, there was significant improvement within its ability to support distributed decision making and collaborative planning through the use of intelligent agents and shared information protocols. Experiments were conducted with distributed C2. For example, during one live fire experiment at 29 Palms fires were coordinated and then controlled using a network centric approach by individual company Fire Support Teams using the same agent functionality available within the ECOC.

With the completion of *Capable Warrior*, the ECOC had progressed from a crude, surrogate command and control system that was so fragile that it could not be located at sea, through a more advanced stage in *Urban Warrior* that not only was capable of emplacement within the secure network of a Navy combatant but also employed intelligent agent decision support systems within the Marine Corps, to a mature prototype demonstrated by the ELB ACTD and the Lab during *Capable Warrior.* Through this experimentation process the potential feasibility of future wide band wireless over-the-horizon communications were demonstrated while the Marine Corps acquired its first real test of tactical computers to share situational awareness and the use of intelligent agents to support decision support systems.

<u>Breaking Paradigms – Ubiquitous Tactical Unmanned Air Vehicles flown by Non-Aviators</u>

Whereas the surrogate information systems of *Hunter Warrior* were used to explore the ramifications of a new concept empowered by emerging technologies, the use of the *Dragon Drone* during Hunter Warrior was intended to change the way Marines perceived unmanned aircraft – UAVs – in the future. Historically, *things-that-fly* – and systems that are intended to shoot down *things-that-fly* -- are controlled by the aviation units. Current Marine *Pioneer* UAVs are flown and controlled by the VMU squadrons of the Marine Aircraft Wings.



The Dragon Drone was flown by the Marine Corps Warfighting Laboratory as an all-purpose UAV testbed for any possible future use of a UAV. In fact one of the first limited objective experiments conducted by the Lab was the use of the Dragon Drone to drop pepper spray non-lethal agents from the air as a means of dispersing crowds and riots before they massed within the immediate proximity of Marines. Other uses included tests at Dugway, Utah, proving grounds of the drone's ability to deliver special sensors in an effort to detect and identify the existence of small traces aerosol of either chemical or biological agents within the atmosphere and the delivery of scatter able micro sensors.

However, the drone became a true paradigm breaker when it was used during *Hunter Warrior* as a surrogate small unit level tactical UAV to conduct reconnaissance beyond the next hill or to track fleeting targets beyond visual range. Although the drone was launched and recovered from rear areas, it was capable of having its camera controlled and the video feed drawn down directly to a tactical ground unit. The ground unit could also control it. Once that ground unit was done with the UAV, it could be released to continue on its GPS controlled track until it returned to its designated recovery zone.

By *Urban Warrior*, the drone had progressed even further such that it was considerably easier to control, had been given a new heavy fuel engine so that it could be deployed aboard Navy ships with Marine Expeditionary Units as a semi-disposable tactical UAV asset, and had been operated by artillery units, light armored reconnaissance units, combat service support units, and by infantry units down to the platoon and squad level. Just as significant, experience with the drone was leading to an easing of air space management concerns involving simultaneous employment of manned aircraft.

As a result of the success of the *Dragon Drone*, the Lab has developed the *Dragon Eye* tactical UAV that is reduced in size from the 80 pounds of *Dragon Drone* to less than 8 pounds in the composite winged *Dragon Eye*. Also GPS guided, the *Dragon Eye* is intended to be an inexpensive, almost disposable tactical UAV that can be operated by a wide range of ground combat units. With its small weight and a GPS-controlled top ceiling of 500 feet it is exempt from formal air space management and truly a ground element item of equipment that can be employed in support of the squad, platoon, and company reconnaissance, surveillance, and target acquisition requirements.

During FY02, over 40 of these UAVs will be fielded by the Lab for operational testing by the ground operating forces as a prototype tactical UAV.

<u>Alternative Concept Demonstrators – The Expeditionary Fire Support System</u>

As the Hunter Warrior experimental concept was under development, it became clear there was a need for a highly mobile fire support system that could be readily deployed internally within helicopters – or the MV-22 – and employed upon arrival either automatically or with a minimum crew to provide immediately responsive fire support to small units in contact. Long range precision naval gunfire was projected to have a time of flight of up to eight minutes from launch. Aircraft were sometimes unavailable due to weather or interruptions in flight schedules. Accordingly, small units on the future battlefield needed an alternative system.

Almost as an afterthought for *Hunter Warrior*, a conceptual expeditionary fire support system modeled on a state-of-the-art French 120mm rifled mortar was included in the force list for the experiment. Since no such system then existed, three wooden boxes filled with sand were used as representational surrogate systems during the experiment and the ECOC computers were used to adjudicate its usage.

Within 17 months of the development of the concept of such a system, the Lab had acquired a French rifled 120mm Mortar and built a portable chassis through Pickatinny Arsenal. Named the *Dragon Fire*, this operational prototype firing system was used as a concept demonstrator against the current program of towed artillery systems. In effect, it provided a visible and functional alternative to howitzers or rockets for the expeditionary fire support role requiring a firing system with an identical mobility profile of the ground combat element that it is supporting.

During *Urban Warrior* gaming and modeling, the mortar demonstrated its superior potential for use in the urban canyons of the city, providing plunging fire to isolate building objectives, breakup counter offensives in dead space behind building complexes, and even as a direct fire system if altered to be breach loading vice muzzle loading. In addition, the Lab's Dragon Fire was joined in several experiments by a French, LAV-mounted rifled 120mm Mortar. Subsequently, the concept for the Dragon Fire's employment was expanded to include a potential third deployment means, loaded internally within the cargo bay of a LAV25 or a LAV logistics variant. Potentially, the Dragon Fire could be deployed in either of three ways – towed by a HUMMWV or LAV, internally within a CH-53E or MV-22 tilt rotor aircraft, or internally within a LAV. Significantly, if internally loaded in a LAV, the capability could be developed to potentially fire the mortar on the move.

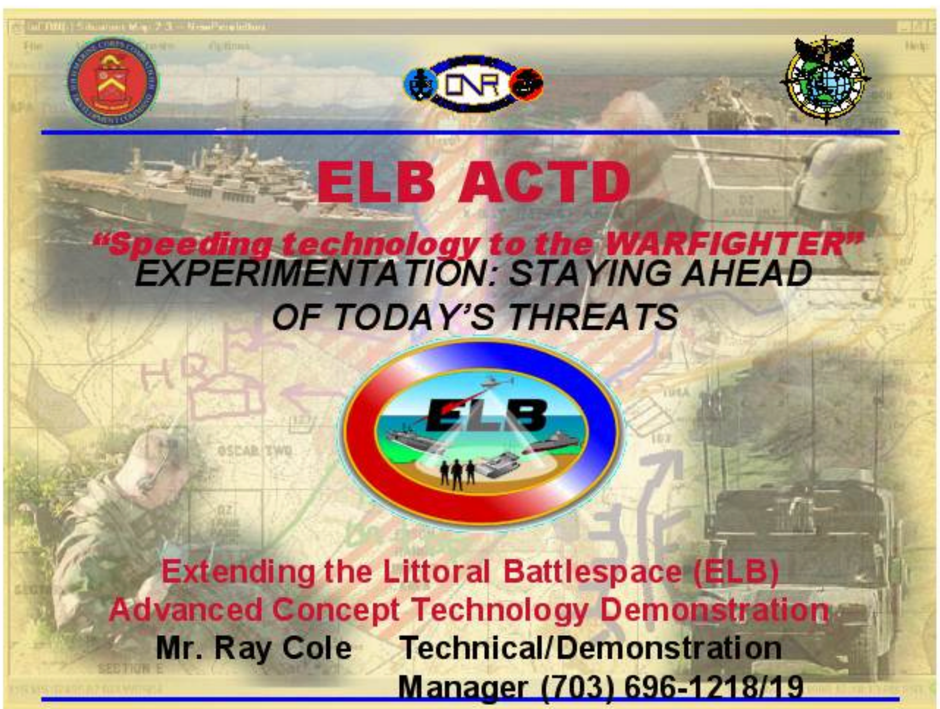
As an alternative concept prototype, the Dragon Fire has been a huge success. It has been embraced by three consecutive commanders at the Lab and is currently under consideration both as a future alternative to the Light Weight 155mm Howitzer as a direct support artillery system for the infantry under some operational concepts as well as a potential replacement or augmenting infantry mortar system to the 81mm Mortar. Its existence has forced the Marine Corps to consider alternatives to current firing systems and operational concepts.

In each of the three cases described above, surrogates were the means that the Marine Corps Warfighting Laboratory used to explore, demonstrate, or challenge future concepts before state-of-the-art technology was available to provide the capability in a fully useable prototype system. As Yogi Berra put it, "the future ain't what it used to be." Using surrogates as the compass to chart the correct direction into the future has already proven its worth.

Experimentation: Staying Ahead of Today's Threats

Raymond Cole (Col. USMC Ret.)

Demonstration/Program Manager
Extending the Littoral Battlespace ACTD



TODAY'S WORLD

ELB ACTD

- Mission - Win decisively, quickly with minimal casualties and collateral damage
- Threat
  - asymmetric vs symmetric
  - complex(urban) vs simple terrain
  - possesses anti-access and anti-denial capabilities
  - capable of delivering or threatening chemical / biological weapons
  - capable of employing information warfare and cyber attacks

4/19/01

1239/3

CHALLENGES

ELB ACTD

- Identifying / prioritizing joint operational requirements
- Joint Operational Requirement and technology matching (skunk works items)
- Rapid prototyping / field demonstration
- Residual / ILS type support to operational forces
- Insertion into programs of record / establishing new programs
- Overcoming the "we already do this better than everyone else in the world" mindset

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MSD-II OBJECTIVES

ELB ACTD

- Enable collaborative planning between dispersed elements at sea and ashore
- Provide secure, high bandwidth, wireless connectivity to the squad level
- Harmonize ELB / US Army digitization
- Determine ELB potential interface to Naval Fires Network to provide Joint Fires
- Stress joint interoperability

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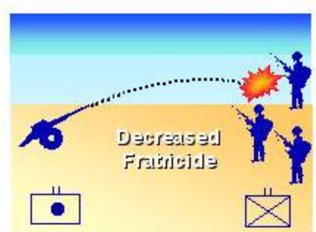
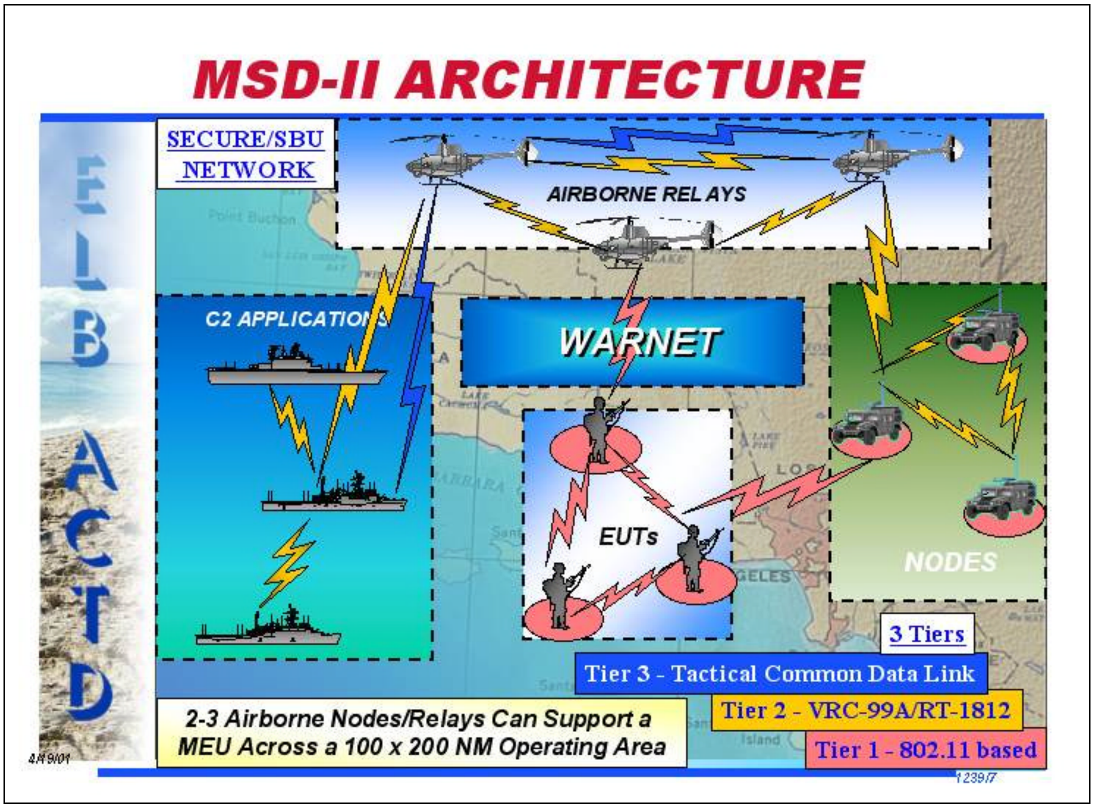
WARFIGHTER FOCUS

Provide secure, high bandwidth, wireless connectivity to the squad level



Enable collaborative planning between dispersed elements at sea or ashore

Facilitate OMFTS/ STOM in the extended littoral battlespace



TECHNICAL DEVELOPMENT
(Three Tiered Architecture)

Tier 1

IEEE 802.11b

- Lucent developed
- ISM Band / Mil band variants
- PCMCIA card size
- Performance:
  - 1Mbps - 11Mbps at 10nm
- NSA Secure Variant under development
- LPI/LPD Variant under development

Tier 2

VRC-99A

- BAE
- L Band
- TDMA based
- Performance:
  - up to 1.2Mbps at 30nm

RT-1812

- ITT
- UHF Band radio
- Cluster head based
- Performance:
  - up to 280Kbps at 20nm

Tier 3

TCDL

- Harris
- Ku Band
- High data rate point-to-point radio system
- Used in architecture to link Tier 2 subnets
- Air to Surface and Air to Air implementations
- Performance:
  - 10.7Mbps at 80nm

ELB ACTD

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TECHNICAL DEVELOPMENT
(C2 APPLICATIONS)

ELB ACTD

- IMMACCS/Shared Net/BVT
  - Confirmed fire mission message threads
  - Validated information exchange with USA ABCS to the brigade level
  - Achieved acceptable Common Tactical Picture (CTP) at the ECOC and the End User Terminal
- GCCS-M (CTP), LAWS (access to fires), DUKE (Secret High Intel), Gale Light (ELINT feed to DUKE)

Action Plan
- Simplifying log-on procedures
- Optimizing software for wireless environment
- Implementing Distributed Server architecture

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TECHNICAL DEVELOPMENT
(SECURITY ARCHITECTURE)

ELB ACTD

- Classified and Sensitive but Unclassified nets within same architecture (Radiant Mercury/TACLANE)
- Secret connectivity between CICs for planning and file transfer
- Secure shore node point the way demo due to delay in delivery of NSA Type 1 secure 802.11
- Demonstrated on the fly EUT hard drive encryption

Joint Information Operations Center's passive collection and attack during FST-3 did not compromise the network

4/19/01 1239/10

TECHNICAL DEVELOPMENT
(INTEROPERABILITY)

ELB ACTD

U.S. Army

- USA Applications over WARNET:
  - Shared Blue and Red PLI
  - Processed Call For Fire requests and responses
  - Exchanged battlefield geometry overlays
  - Facilitated collaborative planning: white boarding, chat, video, file transfer sessions
- Interoperable with WINPOC

U.S. Navy

- TES-N: Database update and transmission of imagery files from USS Coronado to Remote Terminal Console ashore

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TECHNICAL DEVELOPMENT
(SCALABILITY)

ELB ACTD

- Subnetting / bridging with long haul TCDL
- Distributed servers
- Commander's "real time" network management tools
- Focus Study to evaluate operational, system, and technical scalability
- Follow-on to VRC-99A (JTRS Compliant Block 2C) more scalable

Scalability central to Military Utility Assessment

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UPDATED MSD-II READINESS

	UNSUCCESSFUL	PARTIAL	SUCCESSFUL
NETWORK PERFORMANCE		✓	
C2 APPLICATIONS		✓	
ARMY INTEROPERABILITY			✓
NFN INTEROPERABILITY			✓
COMMON TACTICAL PICTURE		✓	
INTRA-SHIP COLLABORATIVE PLANNING		✓	
LONG HAUL TCDL NETWORK		✓	
SUPPORT JOINT TELEMEDICINE ACTD			✓
SUPPORT SMALL UNIT LOGISTICS			✓
SUPPORT RST-V			✓
DEMONSTRATE NETWORK SECURITY		✓	
INITIAL TRAINING FOR MSD-II FORCES		✓	

MSD-II POINT THE WAY DEMOS

ELB ACTD

- C2PC/C2CE/DACT
  - Fielded systems
  - Secret High common tactical picture
  - Fires support client (Beta version)
  - Demonstrated TACLANE tunnel
- JEDI
  - Handheld EUT with simple function set
  - Not scalable to entire network
- Information Security Enhancements
  - SECNET 11- NSA Type 1 802.11 prototype
  - 802.11 Frequency Conversion
  - Virtual Private Network - WARNET not seamless enough
  - On the fly hard drive encryption

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MSD-II CONOPS

E L B A C T D

- ARG/MEU conducting OMFTS within a JTF framework
- JTFEX-like exercise (CPEN, El Centro, Yuma)
- Closely coupled with FBE-I and CW
- At times, providing communications path for NFN, JMO-T, RST-V and SUL
- 7 day demo/8-10 hr demo day/daylight ops only

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TARAWA ARG / 13TH MEU LESSONS LEARNED

E L B A C T D

- Improve shipboard installation process
- Include ELB module in R2P2 training
- Integrated ELB suite into shipboard network
- Add workstations to LFOC, wardroom, and Flag plot to increase flexibility
- Provide grid maps and military unit symbology for whiteboard functionality
- Develop collaborative SOP to optimize whiteboard functionality
- Configure multiple airborne relays
- Pursue EMI filtering/antenna placement/frequency management
- Address cryptographic procedural issues

WARNET(Operational 24/7 for majority of deployment) supported East Timor Humanitarian Assistance, Persian Gulf Operations, USS Cole investigation, Supporting Arms Coordination Center Exercise, Operation Iron Magic

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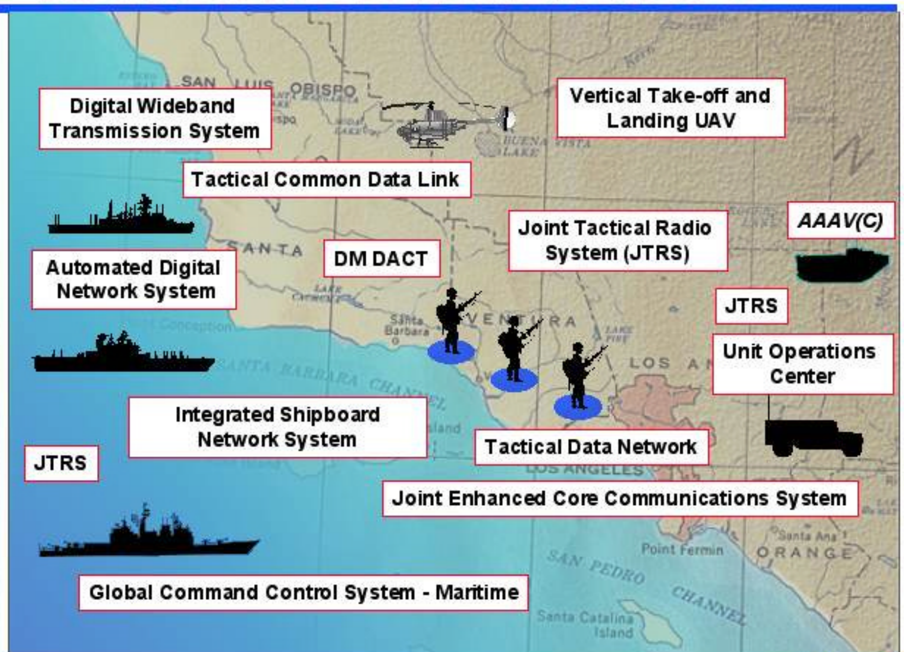
TRANSITION INITIATIVES

ELB ACTD



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SPAWAR HORIZONTAL INTEGRATION 4.X

ELB ACTD

- Concept of Operations
  - Intra Battle Group Wireless Networking -- Wideband RF LOS
  - 3 ships (USS Harry S. Truman, USS Normandy, USS Barry) & USS Coronado
- SPAWAR Horizontal Integration 4.X (FY02-FY04)
  - IT-21 Block 1 Upgrade Demonstration of ELB Tier 2 capability
  - Expeditionary Wireless Networking (DWTS) transition effort merged
- Issues
  - Cost/funding
  - Technical
  - ILS

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ELB VALUE ADDED

- Deployed the first intra-BG, intra-ARG, multi-purpose, high bandwidth network (VRC-99A)
  - Added to SPAWAR Horizontal Integration 4.X to demo intra-BG LOS network capability for IT-21 block upgrade
  - Waveform characteristics to be transitioned to DWTS as the next radio block upgrade
  - Major contributor to JTRS CONOPS, requirements definition, model validation
  - Provided residual assets for fleet use - Tarawa ARG / 13th MEU
- Demonstrated support for NFN connectivity to a RTC
- Demonstrated Army/USMC tactical network interoperability including access to fires
- Providing real-world assessment of the network centric architecture necessary to support dismounted forces

E L B A C T D

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ELB VALUE ADDED

- Demonstrated major enhancements to TCDL programs (H-60B/R/S, combatants, VTUAV, joint ISR programs)
  - Implemented first IP (ethernet) based CDL network interface
  - First shipboard installation of TCDL
  - Funded antenna pointing algorithms for LAMPS - surface combatant Hawklink upgrade
  - First synchronous, 10.7Mbps TCDL link
  - First air-to-air communications capability
  - First air-to-air relay capability
- First military field test of three-tiered JTRS construct
- Evaluating the operational impact of providing situational awareness, access to fires, and C2 capability to the squad level
- Developed a prototype VTUAV Comm relay payload

E L B A C T D

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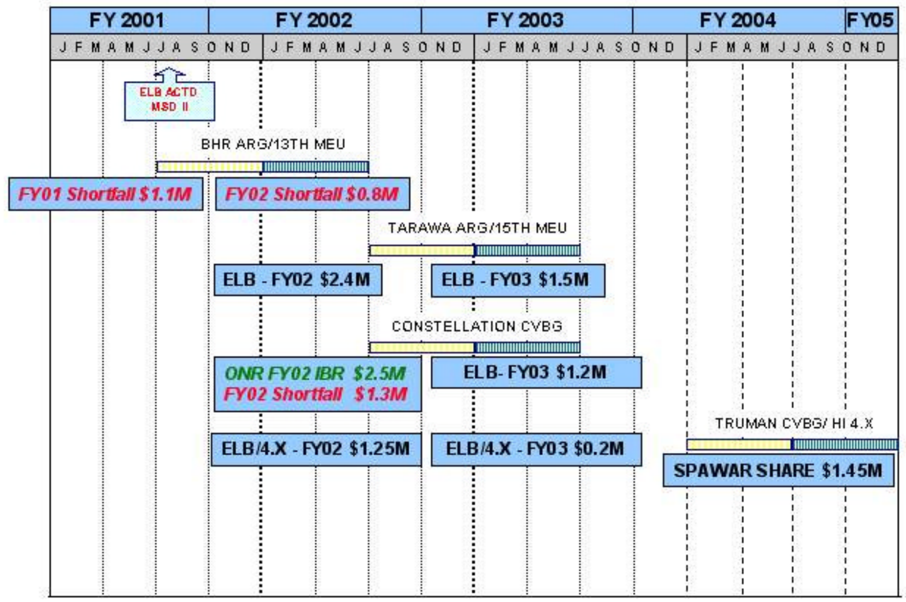
RESIDUAL SCHEDULE



NETWORK EVOLUTION

	FST 1	FST 2	FST 3	(Readiness Demo)	MSD-II Objectives
Network Complexity Attempted					
	3 ground nodes 2 aircraft 10 EUTs 90 mile long haul 2 Tier RF (single net)	4 ground nodes 2 aircraft 25 EUTs 80 mile long haul (1 a/c only) 3 Tier RF (dual subnets)	5 ground nodes 3 aircraft 4 ships 45 EUTs 110 mile long haul 3 Tier RF (multiple subnets)	(8) (4) (50)	8 ground nodes 4 aircraft 4 ships 96 EUTs 200 mile long haul 3 Tier RF (multiple subnets)
Network Performance					
• *Available backbone BW*	100 kbps	600 kbps	1 Mbps		1.5 Mbps
• *average daily ECOC to CV packet loss*	37% (stationary)	22% (stationary), 43% (on the move)	40% (on the move)		20% (stationary), 20% (on the move)
• *average ECOC to CV latency*	2.2 sec	400 msec	1.2 sec		1 sec
• *Average Connectivity*			In/out comms 50% (<10% packet loss)		
Test Environment					
• *location*	• SOCAL - no terrain obstructions	• MS - significant foliage obstructions, harsh environment for high freq	• SOCAL - significant terrain obstructions		• SOCAL - AZ significant terrain obstructions
• *military participation*	• None	• SPMAGTF	• I MEF, C3F, Army	(Army)	• I MEF, C3F, Army
• *scenarios*	• Static laydowns	• RSTA, STOM	• RSTA, STOM		• RSTA, STOM

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RESIDUAL INITIATIVES

ELB ACTD

- BONHOMME RICHARD ARG/13TH MEU (Deploy Jan 02):
  - MSD II installations (BHR/PH only)
  - Integration efforts underway/Continued coordination with PHIBRON 3
- TARAWA ARG/15TH MEU (Deploy Jan 03):
  - Budgeted in FY02/03
  - Architecture decision: July 01
- CONSTELLATION CVBG (Deploy Jan 03):
  - Near term integrated RF BLOS wideband network capability
  - 4-5 ships, multiple airborne relays
- TRUMAN CVBG (Deploy Jul 04):
  - HI 4.X IT-21 Block upgrade for new network capability (Intra-BG Wireless Network)
  - Includes advanced technologies for RF LOS networks, efficient BW utilization, increased network throughput, & digital modernization
  - 3 deploying ships (USS Harry S. Truman, USS Normandy, USS Mahan), and USS Coronado

4/19/01 1239/23

SUMMARY

ELB ACTD

- Focus on an asymmetric threat
- Counter the threat with dominant Situational Awareness
- Employ ACTDs to leverage cutting edge technologies and COTS products
- Emphasize Residual and Transition Programs
- Aggressively RED Team programs of record and all ACTDs

Tomorrow's threats will take away our superior target acquisition and engagement capabilities!

4/19/01 1239/24

Demonstration: Interoperability at the Information Level

Anthony Wood (Col. USMC Ret.)
Director of Applied Research
Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo (CA)

The decided advantages of an ***information-centric*** computer environment, presented at the third annual Office of Naval Research (ONR) sponsored ***Workshop on Collaborative Decision-Support*** (Quantico, VA, June 5, 2001), are highlighted herein. Of particular significance is the ability of software agents to reason about events, collaborate intelligently with each other and users, and transmit alerts across multiple application domains.

For the past 20 years the military services have suffered under the limitations of stove-piped computer software applications that function as discrete entities within a fragmented data-processing environment. Lack of interoperability has been identified by numerous think tanks, advisory boards, and studies, as the primary information systems problem (e.g., Army Science Board 2000, Air Force SAB 2000 Command and Control Study, and NSB Network-Centric Naval Forces 2000). Yet, despite this level of attention, all attempts to achieve ***interoperability*** within the current ***data-centric*** information systems environment have proven to be expensive, unreliable, and generally unsuccessful.

Why is this so? The expectations of true interoperability are threefold. First, interoperable applications should be able to integrate related functional sequences in a seamless and user transparent manner. Second, this level of integration assumes the sharing of ***information*** from one application to another, so that the results of the functional sequence are automatically available and similarly interpreted by the other application. And third, any of the applications should be able to enter or exit the integrated interoperable environment without jeopardizing the continued operation of the other applications. These conditions simply cannot be achieved by computer software that processes numbers and meaningless text with predetermined algorithmic solutions through hard-coded dumb data links.

Past approaches to interoperability have basically fallen into three categories. Attempts to create common architectures have largely failed because this approach essentially requires existing systems to be re-implemented in the common (i.e., new) architecture. Attempts to create bridges between applications within a confederation of linked systems have been faced with three major obstacles. First, the large number of bridges required (i.e., the square of the number of applications). Second, the fragility associated with hard-coded inter-system data linkages. Third, the cost of maintaining such linkages in a continuously evolving information systems environment. The third category of approaches has focused on achieving interoperability at the interface boundary. For anything other than limited presentation and visualization capabilities, this approach cannot accommodate dynamic data flows, let alone constant changes at the more useful information level.

(Editor's note: This is the text of a brochure that was provided to Workshop participants as background information for the live demonstration, which was narrated by Col. Wood.)

These obstacles to interoperability and integration are largely overcome in an information-centric software systems environment by embedding in the software some understanding of the information being processed. How is this possible? Surely computers cannot be expected to understand anything. Aren't they just dumb electronic machines that simply execute programmed instructions without any regard to what either the instructions, or the information to which the instructions apply, mean? The answer is no, it is all a matter of ***representation*** (i.e., how the information is structured in the computer).

As shown in the centerfold diagram, ***the integration and interoperability capabilities of an information-centric software system allow agents in one application to notify agents in other applications of events occurring in multiple domains***. For example, the Engagement Agent in the tactical Integrated Marine Multi-Agent Command and Control System (IMMACCS) is able to advise appropriate agents in the logistical SEAWAY application whenever a Supply Point ashore is threatened by enemy activity. This may result in the timely rescheduling or redirection of a planned re-supply mission. The ***agents are able to communicate across multiple applications at the information level through the common language of the ontological framework***. Similarly, the SEAWAY application is able to rely on the Integrated Computerized Deployment System (ICODES) to maintain in-transit cargo visibility, down to the location of a supply item in a container on-board a MTMC (Military Traffic Management Command, USTRANSCOM) ship en-route to an Intermediate Staging and Embarkation Port (ISEP). This kind of interoperability cannot be achieved in a ***data-centric*** systems environment, where computer-based reasoning cannot take place and linkages between applications are limited to the transmission of data messages that depend entirely on human interpretation.

The term ***information-centric*** refers to the representation of information in the computer, not to the way it is actually stored in a digital machine. This distinction between ***representation*** and ***storage*** is important, and relevant far beyond the realm of computers. When we write a note with a pencil on a sheet of paper, the content (i.e., meaning) of the note is unrelated to the storage device. A sheet of paper is designed to be a very efficient storage medium that can be easily stacked in sets of hundreds, filed in folders, folded, bound into volumes, and so on. However, all of this is unrelated to the content of the written note on the paper. This content represents the meaning of the sheet of paper. It constitutes the purpose of the paper and governs what we do with the sheet of paper (i.e., its use). In other words, the nature and efficiency of the storage medium is more often than not unrelated to the content or representation that is stored in the medium.

In the same sense the way in which we store bits (i.e., 0s and 1s) in a digital computer is unrelated to the meaning of what we have stored. When computers first became available they were exploited for their fast, repetitive computational capabilities and their enormous storage capacity. Application software development progressed rapidly in a ***data-centric*** environment. Content was stored as data that were fed into algorithms to produce solutions to predefined problems in a static problem solving context. It is surprising that such a simplistic and artificially contrived problem solving environment was found to be acceptable for several decades of intensive computer technology development.

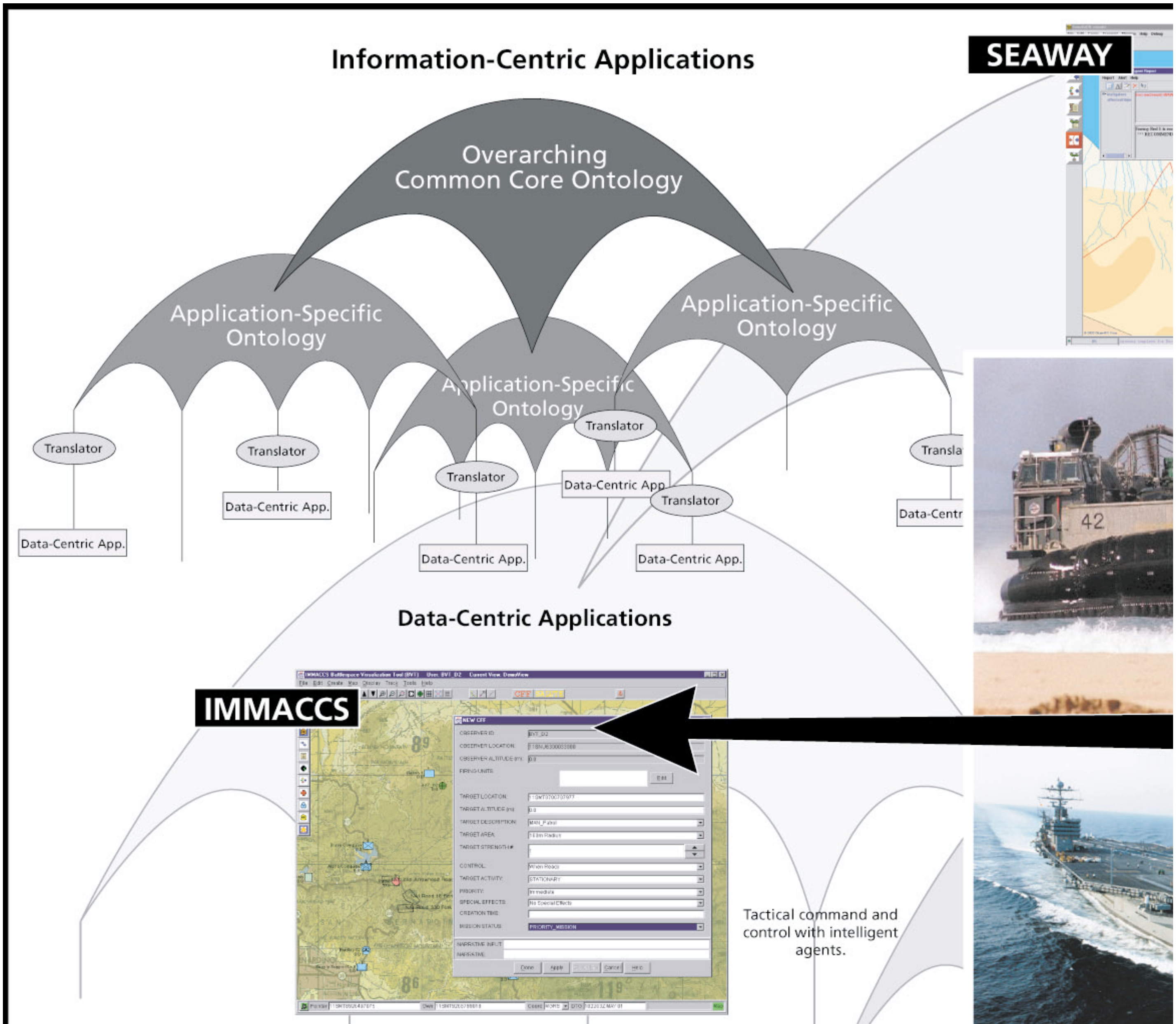
When we established the Collaborative Agent Design Research Center at Cal Poly in 1986, we had a vision. We envisioned that users should be able to sit down at a computer terminal and solve problems collaboratively with the computer. The computer should be able to continuously assist and advise the user during the decision making process. Moreover, we postulated that one should be able to develop software modules that could spontaneously react in near real-time to changing events in the problem situation, analyze the impact of the events, propose alternative courses of action, and evaluate the merits of such proposals. What we soon discovered, as we naively set out to develop an intelligent decision-support system, is that we could not make much headway with ***data*** in a dynamically changing problem environment.

Initially focusing on engineering design, we had no difficulties at all developing a software module that could calculate the daylight available inside a room, as long as we specified to the computer the precise location and dimensions of the window, the geometry of the room, and made some assumptions about external conditions. However, it did not seem possible for the computer to determine on its own that there was a need for a window and where that window might be best located. The ability of the computer to make these determinations was paramount to us. We wanted the computer to be a useful assistant that we could collaborate with as we explored alternative design solutions. In short, we wanted the computer to function ***intelligently*** in a dynamic environment, continuously looking for opportunities to assist, suggest, evaluate, and alert us whenever we pursued solution alternatives that were essentially not feasible.

We soon realized that to function in this role our software modules had to be able to ***reason***. To be able to reason the computer needs to have something akin to ***understanding*** of the ***context*** within which it is supposed to reason. The human cognitive system builds context from knowledge and experience using ***information*** (i.e., data with attributes and relationships) as its basic building block. Interestingly enough the storage medium of the information, knowledge and context held by the human brain is billions of neurons and trillions of connections (i.e., synapses) among these neurons that are as unrelated to each other as a pencilled note and the sheet of paper on which it is stored.

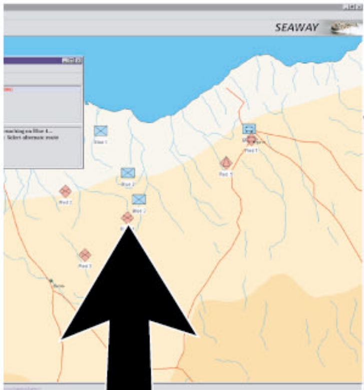
What gives meaning to the written note is its ***representation*** within the framework of a language (e.g., English) that can be understood by the reader. Similarly, in a computer we can establish the notion of ***meaning*** if the stored data are represented in an ontological framework of objects, their characteristics, and their interrelationships. How these objects, characteristics and relationships are actually stored at the lowest level of bits (i.e., 0s and 1s) in the computer is immaterial to the ability of the computer to undertake reasoning tasks. The conversion of these bits into data and the transformation of data into information, knowledge and context takes place at higher levels, and is ultimately made possible by the skillful construction of a network of richly described objects and their relationships that represent those physical and conceptual aspects of the real world that the computer is required to reason about.

This is what is meant by an information-centric computer-based decision-support environment. One can further argue that to refer to the ability of computers to ***understand*** and ***reason*** about ***information*** is no more or less of a trick of our imagination than to refer to the ability of human beings to understand and reason about information. In other words, the countless minuscule charges that are stored in the neurons of the human nervous system are no closer to the representation of information than the bits (i.e., 0s and 1s) that are stored in a digital computer. However, whereas the human cognitive

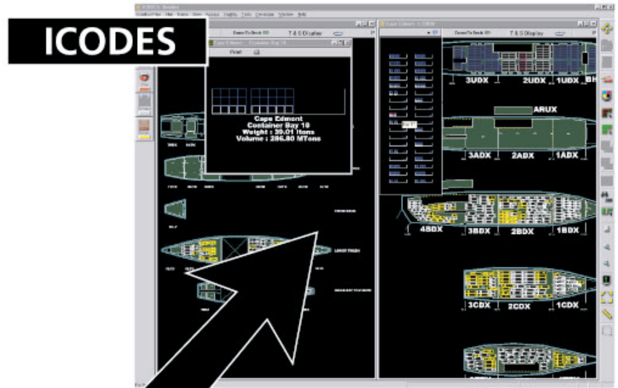


Acknowledgements

The IMMACCS tactical command and control system is sponsored by the Marine Corps Warfighting Laboratory as a team effort involving the Collaborative Agent Design Research Center, Cal Poly, San Luis Obispo (overall architecture, object model, agent engine, and object browser interface), the Jet Propulsion Laboratory, Cal Tech, Pasadena (Shared Net object-serving communication facility), FGM Inc., San Diego (Battlefield Visualization Tool (BVT) user interface and MCSIT Translator), SPAWAR Systems Center, San Diego (System Engineering Integration), and the Navy Research Laboratory, Stennis Space Center, Mississippi (infrastructure objects). The ICODES ship load planning system is sponsored by the Military Traffic Management Command of USTRANSCOM, and SEAWAY, CIAT, and OTIS are sponsored by the Office of Naval Research under the Logistics Program (Dr. Phillip Abraham). The CADRC and CDM Technologies, Inc, are jointly responsible for the development of ICODES, SEAWAY, CIAT and OTIS.

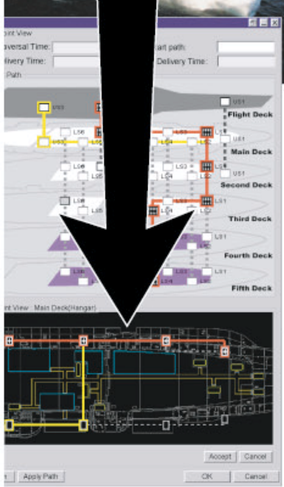


Logistical command and control in support of expeditionary warfare.

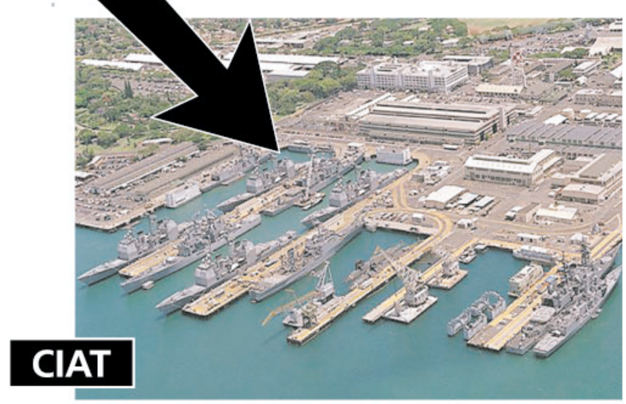


Agent-assisted ship load planning.

Agent-based collaborative management of port facilities and ship berthing.



Planning and monitoring of ordnance movements with agent assistance, on aircraft carriers.



system automatically converts this collection of charges into information and knowledge, in the computer we have to construct the framework and mechanism for this conversion. Such a framework of objects, attributes and relationships provides a system of integrated software applications with a common language that allows software modules (call them ***agents*** if you like) to ***reason*** about events, monitor changes in the problem situation, and collaborate with each other as they actively assist the user(s) during the decision making process. One can say that this ***ontological framework*** is a virtual representation of the real world problem domain, and that the agents are dynamic tools capable of pursuing objectives, extracting and applying knowledge, communicating, and collaboratively assisting the user(s) in the solution of current and future real world problems.

An increasing number of commercial companies are starting to take advantage of the higher level collaborative assistance capabilities of computers to improve their competitive edge and overcome potential customer service difficulties. A good example is the timely detection of the fraudulent use of telephone credit card numbers. Telephone companies deal with several million calls each day, far too many for monitoring by human detectives. Instead, they have implemented intelligent computer software modules that monitor certain information relating to telephone calls and relate that information to the historical records of individual telephone users. The key to this capability is that telephone call data such as time-of-day, length of call, origin of call, and destination are stored in the computer as an information structure containing data objects, relationships, and some attributes for each data object. For example, the data "Colombia" may have the attributes international, South America, uncommon telephone call destination, attached to it. In addition, relationships are established dynamically between "Colombia" the telephone number of the caller, the telephone number being called, the time-of-day of the call, and so on. The result is a network of objects with attributes and relationships that is very different from the data stored in a typical commercial data-mart. This network constitutes information (rather than data) and allows hundreds of software ***agents*** to monitor telephone connections and detect apparent anomalies. What is particularly attractive about this fairly straightforward application of ***information-centric*** technology, is that the software ***agents*** do not have to listen in on the actual telephone conversations to detect possibly fraudulent activities. However, from the telephone company's point of view this use of expert ***agents*** saves millions of dollars each year in lost revenues.

The ability to achieve ***interoperability at the information level*** eliminates the many obstacles that plague data-centric confederations of software systems. In particular, it obviates the need for hard coded data bridges between discrete applications and allows the data-centric requirement for predefined solutions to be replaced by a tool kit of powerful agents that can provide useful assistance in a dynamically changing collaborative decision making environment.

Information-Centric Decision-Support Systems: A Blueprint for '*Interoperability*'

Jens Pohl, Ph.D.
Collaborative Agent Design Research Center
Cal Poly, San Luis Obispo, CA, USA

For the past 20 years the US military services have suffered under the limitations of stove-piped computer software applications that function as discrete entities within a fragmented data-processing environment. Lack of interoperability has been identified by numerous think tanks, advisory boards, and studies, as the primary information systems problem (e.g., Army Science Board 2000, Air Force SAB 2000 Command and Control Study, and NSB Network-Centric Naval Forces 2000). Yet, despite this level of attention, all attempts to achieve ***interoperability*** within the current ***data-centric*** information systems environment have proven to be expensive, unreliable, and generally unsuccessful.

The Apparently Elusive Goal of '*Interoperability*'

The expectations of true interoperability are threefold. First, interoperable applications should be able to integrate related functional sequences in a seamless and user transparent manner. Second, this level of integration assumes the sharing of ***information*** from one application to another, so that the results of the functional sequence are automatically available and similarly interpreted by the other application. And third, any of the applications should be able to enter or exit the integrated interoperable environment without jeopardizing the continued operation of the other applications. These conditions simply cannot be achieved by computer software that processes numbers and meaningless text with predetermined algorithmic solutions through hard-coded dumb data links.

Past approaches to interoperability have basically fallen into three categories. Attempts to create common architectures have largely failed because this approach essentially requires existing systems to be re-implemented in the common (i.e., new) architecture. Attempts to create bridges between applications within a confederation of linked systems have been faced with three major obstacles. First, the large number of bridges required (i.e., the square of the number of applications). Second, the fragility associated with hard-coded inter-system data linkages. Third, the cost of maintaining such linkages in a continuously evolving information systems environment. The third category of approaches has focused on achieving interoperability at the interface boundary. For anything other than limited presentation and visualization capabilities, this approach cannot accommodate dynamic data flows, let alone constant changes at the more useful information level.

These obstacles to interoperability and integration are largely overcome in an information-centric software systems environment by embedding in the software some understanding of the information being processed. How is this possible? Surely computers cannot be expected to understand anything. Aren't they just dumb electronic machines that simply execute programmed instructions without any regard to what either the instructions, or the information to which the instructions apply, mean? The answer is no, it is all a matter of ***representation*** (i.e., how the information is structured in the computer).

The Notion of '*Information-Centric*'

The term ***information-centric*** refers to the representation of information in the computer, not to the way it is actually stored in a digital machine. This distinction between ***representation*** and ***storage*** is important, and relevant far beyond the realm of computers. When we write a note with a pencil on a sheet of paper, the content (i.e., meaning) of the note is unrelated to the storage device. A sheet of paper is designed to be a very efficient storage medium that can be easily stacked in sets of hundreds, filed in folders, bound into volumes, folded, and so on. However, all of this is unrelated to the content of the written note on the paper. This content represents the meaning of the sheet of paper. It constitutes the purpose of the paper and governs what we do with the sheet of paper (i.e., its use). In other words, the nature and efficiency of the storage medium is more often than not unrelated to the content or representation that is stored in the medium.

In the same sense, the way in which we store bits (i.e., 0s and 1s) in a digital computer is unrelated to the meaning of what we have stored. When computers first became available they were exploited for their fast, repetitive computational capabilities and their enormous storage capacity. Application software development progressed rapidly in a ***data-centric*** environment. Content was stored as data that were fed into algorithms to produce solutions to predefined problems in a static problem solving context. It is surprising that such a simplistic and artificially contrived problem solving environment was found to be acceptable for several decades of intensive computer technology development.

When we established the Collaborative Agent Design Research Center at Cal Poly in 1986, we had a vision. We envisioned that users should be able to sit down at a computer terminal and solve problems collaboratively with the computer. The computer should be able to continuously assist and advise the user during the decision-making process. Moreover, we postulated that one should be able to develop software modules that could spontaneously react in near real-time to changing events in the problem situation, analyze the impact of the events, propose alternative courses of action, and evaluate the merits of such proposals. What we soon discovered, as we naively set out to develop an intelligent decision-support system, is that we could not make much headway with ***data*** in a dynamically changing problem environment.

Initially focusing on engineering design, we had no difficulties at all developing a software module that could calculate the daylight available inside a room, as long as we specified to the computer the precise location and dimensions of the window, the geometry of the room, and made some assumptions about external conditions. However, it did not seem possible for the computer to determine on its own that there was a need for a window and where that window might be best located. The ability of the computer to make these determinations was paramount to us. We wanted the computer to be a useful assistant that we could collaborate with as we explored alternative design solutions. In short, we wanted the computer to function ***intelligently*** in a dynamic environment, continuously looking for opportunities to assist, suggest, evaluate, and, in particular, alert us whenever we pursued solution alternatives that were essentially not practical or even feasible.

We soon realized that to function in this role our software modules had to be able to ***reason***. However, to be able to reason the computer needs to have something akin to ***understanding*** of the ***context*** within which it is supposed to reason. The human cognitive system builds context from knowledge and experience using ***information*** (i.e., data with attributes and relationships) as its basic building block. Interestingly enough the storage medium of the information, knowledge and context held by the human brain is billions of neurons and trillions of connections (i.e., synapses) among these neurons that are as unrelated to each other as a pencilled note and the sheet of paper on which it is stored.

What gives meaning to the written note is its ***representation*** within the framework of a language (e.g., English) that can be understood by the reader. Similarly, in a computer we can establish the notion of ***meaning*** if the stored data are represented in an ontological framework of objects, their characteristics, and their interrelationships. How these objects, characteristics and relationships are actually stored at the lowest level of bits (i.e., 0s and 1s) in the computer is immaterial to the ability of the computer to undertake reasoning tasks. The conversion of these bits into data and the transformation of data into information, knowledge and context takes place at higher levels, and is ultimately made possible by the skillful construction of a network of richly described objects and their relationships that represent those physical and conceptual aspects of the real world that the computer is required to reason about.

This is what is meant by an information-centric computer-based decision-support environment. One can further argue that to refer to the ability of computers to ***understand*** and ***reason*** about ***information*** is no more or less of a trick of our imagination than to refer to the ability of human beings to understand and reason about information. In other words, the countless minuscule charges that are stored in the neurons of the human nervous system are no closer to the representation of information than the bits (i.e., 0s and 1s) that are stored in a digital computer. However, whereas the human cognitive system automatically converts this collection of charges into information and knowledge, in the computer we have to construct the framework and mechanism for this conversion Such a framework of objects, attributes and relationships provides a system of integrated software applications with a common language that allows software modules (now popularly referred to as ***agents***) to ***reason*** about events, monitor changes in the problem situation, and collaborate with each other as they actively assist the user(s) during the decision-making process. One can say that this ***ontological framework*** is a virtual representation of the real world problem domain, and that the agents are dynamic tools capable of pursuing objectives, extracting and applying knowledge, communicating, and collaboratively assisting the user(s) in the solution of current and future real world problems.

Definitions: Data, Information, and Knowledge

It is often lamented that we human beings are suffering from an ***information overload***. This is a myth, as shown in Fig.1 there is no information overload. Instead we are suffering from a data overload. The confusion between data and information is not readily apparent and requires further explanation. Unorganized data are voluminous but of very little value. Over the past 15 years, industry and commerce have made significant efforts to rearrange this unorganized data into purposeful data, utilizing various kinds of database management systems. However, even in this organized form, we are still dealing with data and not information.

Data are defined as numbers and words without relationships. In reference to Fig.2, the words “town”, “dog”, “Tuesday”, “rain”, “inches”, and “min”, have little if any meaning without relationships. However, linked together in the sentence: "On Tuesday, 8 inches of rain fell in 10 min."; they become information. If we then add the context of a particular geographical region, pertinent historical climatic records, and some specific hydrological information relating to soil conditions and behavior, we could perhaps infer that: "Rainfall of such magnitude is likely to cause flooding and landslides." This becomes knowledge.

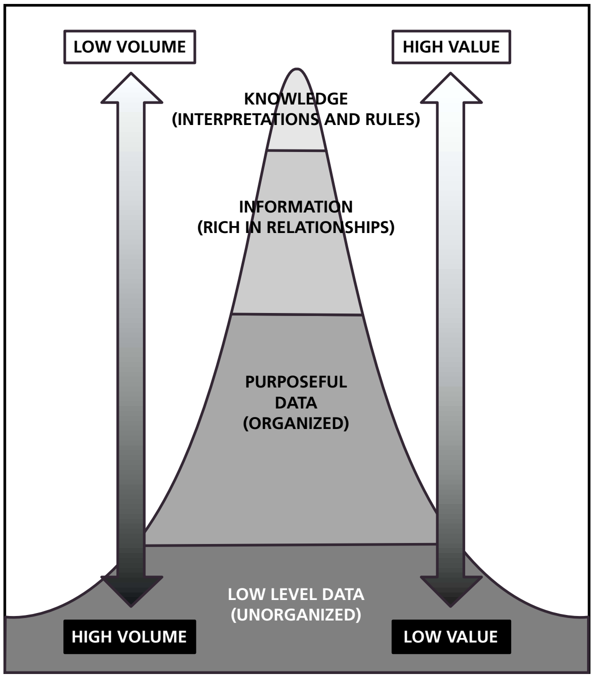


Fig.1: The ***information overload*** myth

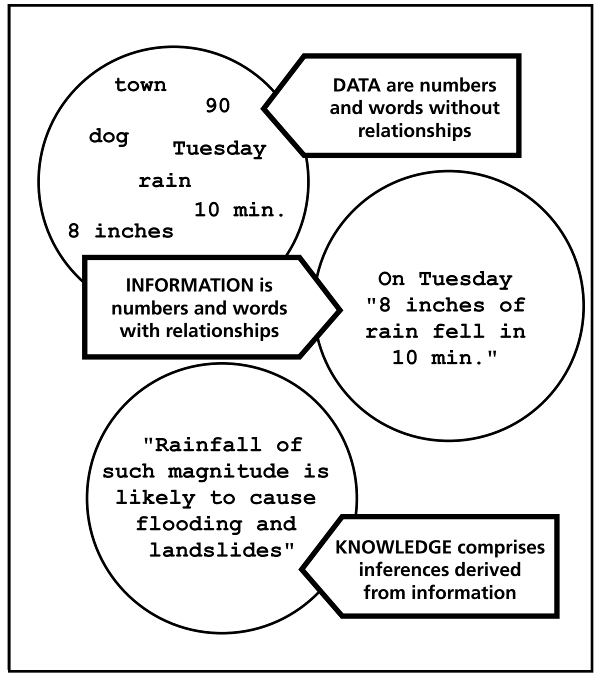


Fig.2: Data, information and knowledge

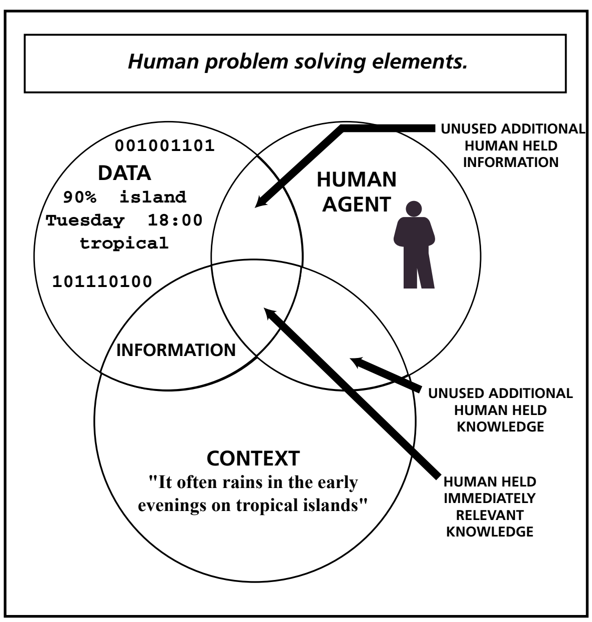


Fig.3: Unassisted problem solving

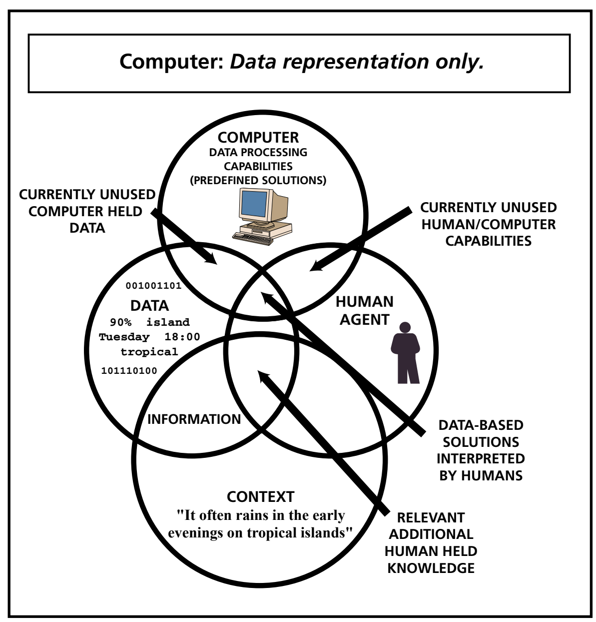


Fig.4: Limited data-processing assistance

Context is normally associated solely with human cognitive capabilities. Prior to the advent of computers, it was entirely up to the human agent to convert data into information and to infer knowledge through the addition of context. However, the human cognitive system performs this function subconsciously (i.e., automatically); therefore, prior to the advent of computers, the difference between data and information was an academic question that had little practical significance in the real world of day-to-day activities. As shown in Fig.3, the intersection of the data, human agent and context realms provides a segment of immediately relevant knowledge.

The Data-Centric Evolution of Computer Software

When computers entered on the scene, they were first used exclusively for processing data. In fact, even in the 1980s computer centers were commonly referred to as data-processing centers. It can be seen in Fig.4 that the context realm remained outside the computer realm. Therefore, the availability of computers did not change the need for the human agent to interpret data into information and infer knowledge through the application of context. The relegation of computers to data-processing tasks is the underlying reason why even today, as we enter the 21st Century, computers are still utilized in only a very limited decision-support role. As shown in Fig.5, in this limited computer-assistance environment human decision makers typically collaborate with each other utilizing all available communication modes (e.g., telephone, FAX, e-mail, letters, face-to-face meetings). Virtually every human agent utilizes a personal computer to assist in various computational tasks. While these computers have some data sharing capabilities in a networked environment, they cannot directly collaborate with each other to assist the human decision makers in the performance of decision-making tasks. Each computer is typically limited to providing relatively low-level data-processing assistance to its owner. The interpretation of data, the inferencing of knowledge, and the collaborative teamwork that is required in complex decision-making situations remains the exclusive province of the human agents. In other words, without access to information and at least some limited context, the computer cannot participate in a distributed collaborative problem-solving arena.

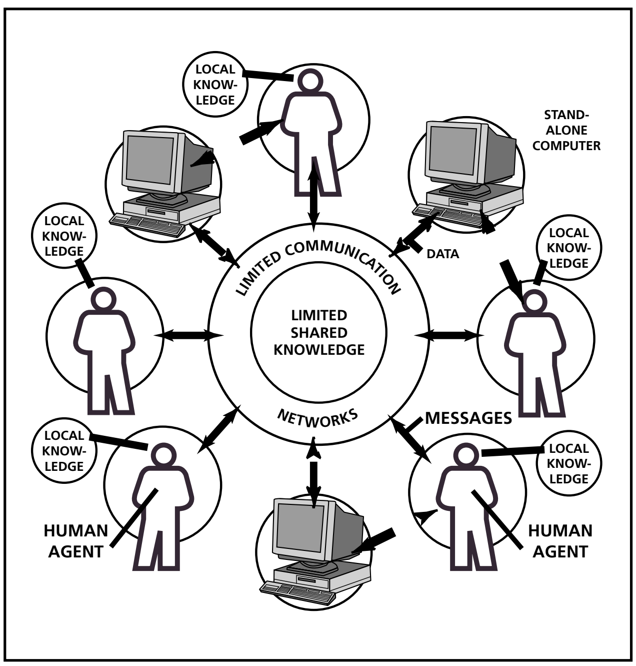


Fig.5: Limited computer assistance

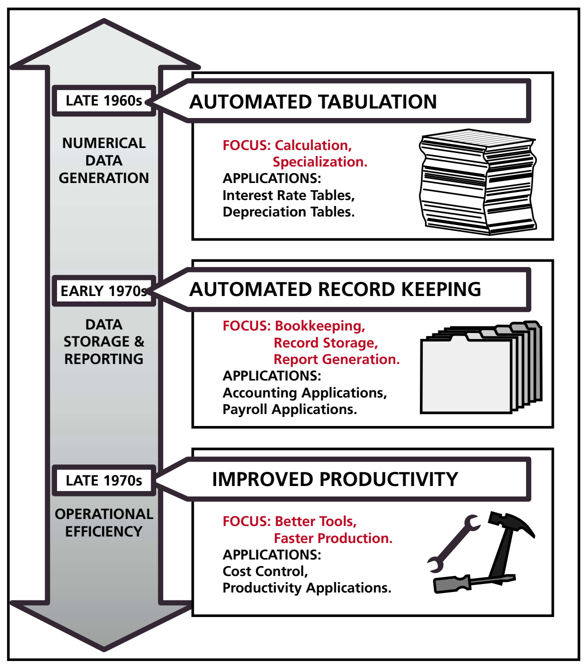


Fig.6: Evolution of business intelligence (A)

In this regard, it is of interest to briefly trace the historical influence of evolving computer capabilities on business processes and organizational structures. When the computer first became more widely available as an affordable computational device in the late 1960s, it was applied immediately to specialized numerical calculation tasks such as interest rate tables and depreciation tables (Fig.6). During the early 1970s, these computational tasks broadened to encompass bookkeeping, record storage, and report generation. Tedious business management functions were taken over by computer-based accounting and payroll applications. By the late 1970s, the focus turned to improving productivity using the computer as an improved automation tool to increase and monitor operational efficiency.

In the early 1980s (Fig.7), the business world had gained sufficient confidence in the reliability, persistence, and continued development of computer technology to consider computers to be a permanent and powerful data-processing tool. Accordingly, businesses were willing to reorganize their work flow as a consequence of the functional integration of the computer. More comprehensive office management applications led to the restructuring of the work flow.

By the late 1980s, this had led to a wholesale re-engineering of the organizational structure of many businesses with the objective of simplifying, streamlining, and downsizing. It became clear that many functional positions and some entire departments could be eliminated and replaced by integrated office automation systems. During the early 1990s, the problems associated with massive unorganized data storage became apparent, and with the availability of much improved database management systems, data were organized into mostly relational databases. This marked the beginning of ordered-data archiving and held out the promise of access to any past or current data and reporting capabilities in whatever form management desired.

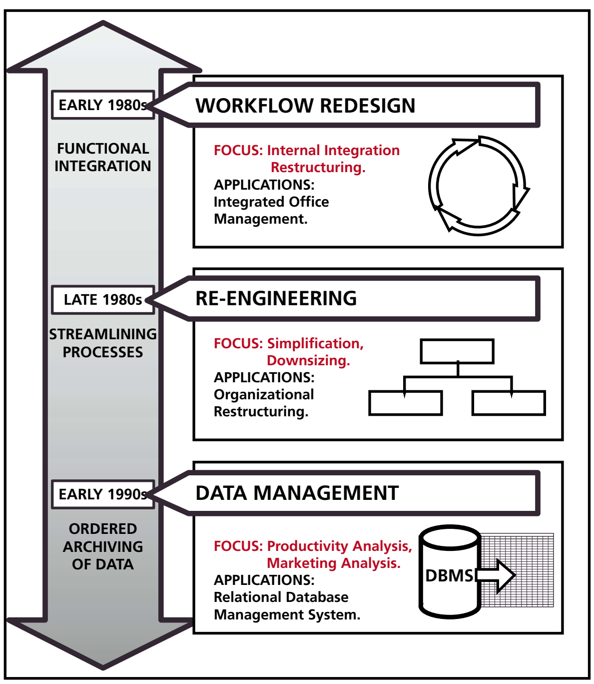


Fig.7: Evolution of business intelligence (B)

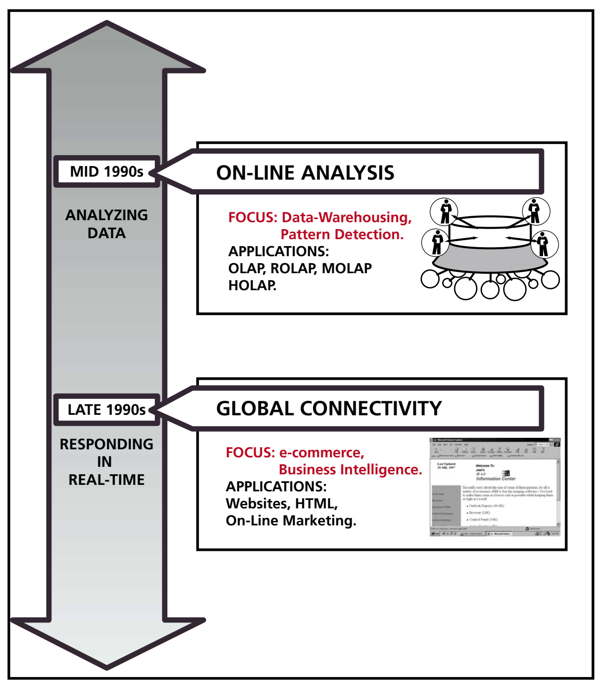


Fig.8: Evolution of business intelligence (C)

However, by the mid 1990s (Fig.8), the quickening pace of business in the light of greater competition increased the need for a higher level of data analysis, faster response, and more accurate pattern detection capabilities. During this period, the concepts of data-warehouses, data-marts, and On-Line Analytical Processing (OLAP) tools were conceived and rapidly implemented (Humphries et al. 1999). Since then, the term 'business intelligence' has been freely used to describe a need for the continuous monitoring of business trends, market share, and customer preferences.

In the late 1990s, the survival pressure on business increased with the need for real-time responsiveness in an Internet-based global e-commerce environment. By the end of the 20th Century, business began to seriously suffer from the limitations of a data-processing environment. The e-commerce environment presented attractive opportunities for collecting customer profiles for the implementation of on-line marketing strategies with enormous revenue potential. However, the expectations for automatically extracting useful information from low-level data could not be satisfied by the methods available. These methods ranged from relatively simple keyword and thematic indexing procedures to more complex language-processing tools utilizing statistical and heuristic approaches (Denis 2000, Verity 1997).

The major obstacle confronted by all of these information-extraction approaches is the unavailability of adequate context (Pedersen and Bruce 1998). As shown previously in Fig.4, a computer-based ***data-processing*** environment does not allow for the representation of context. Therefore, in such an environment, it is left largely to the human user to interpret the data elements that are processed by the computer.

Methods for representing information and knowledge in a computer have been a subject of research for the past 40 years, particularly in the field of 'artificial intelligence' (Ginsberg 1993). However, these studies were mostly focussed on narrow application domains and did not generate wide-spread interest even in computer science circles. For example even today, at the beginning of the 21st Century, it is difficult to find an undergraduate computer science degree program in the US that offers a core curriculum class dealing predominantly with the representation of information in a computer.

The Representation of '*Context*' in a Computer

Conceptually, to represent information in a computer, it is necessary to move the context circle in Fig.4 upward into the realm of the computer (Fig.9). This allows data to enter the computer in a contextual framework, as information. The intersection of the data, context, and human agent circles provide areas in which information and knowledge are held in the computer. The prevailing approach for the practical implementation of the conceptual diagram shown in Fig.9 is briefly outlined below. As discussed earlier (Fig.2), the principal elements of information are data and relationships. We know how data can be represented in the computer but how can the relationships be represented? The most useful approach available today is to define an ontology of the particular application domain in the form of an object model. This requires the identification of the objects (i.e., elements) that play a role in the domain and the relationships among these objects (Fig.10). Each object, whether physical (e.g., car, person, building, etc.) or conceptual (e.g., event, privacy, security, etc.) is first described in terms of its behavioral characteristics. For example, a ***car*** is a kind of ***land conveyance***. As a child object of the ***land conveyance*** object, it automatically inherits all of the characteristics of the former and adds some more specialized characteristics of its own (Fig.11). Similarly, a ***land conveyance*** is a kind of ***conveyance*** and therefore inherits all of the characteristics of the latter. This powerful notion of inheritance is well supported by object-oriented computer languages such as C++ (Stroustrup 1987) and Java (Horstmann and Cornell 1999) that support the mainstream of applications software development today.

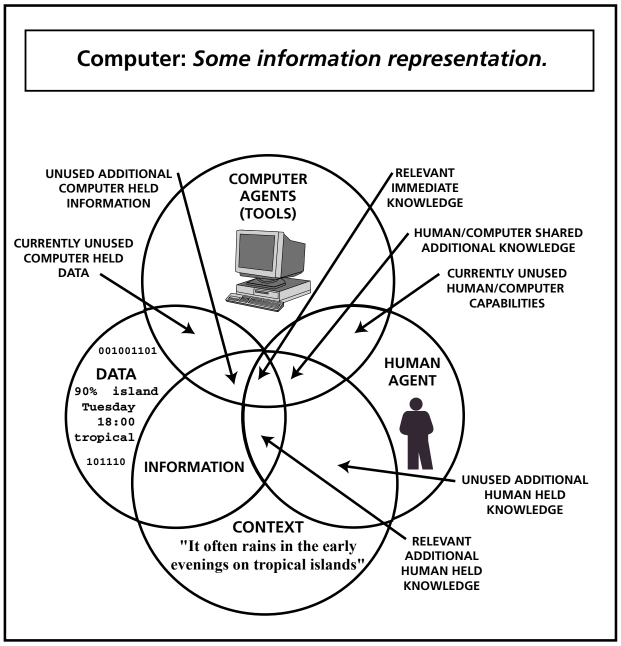


Fig.9: Early human-computer partnership

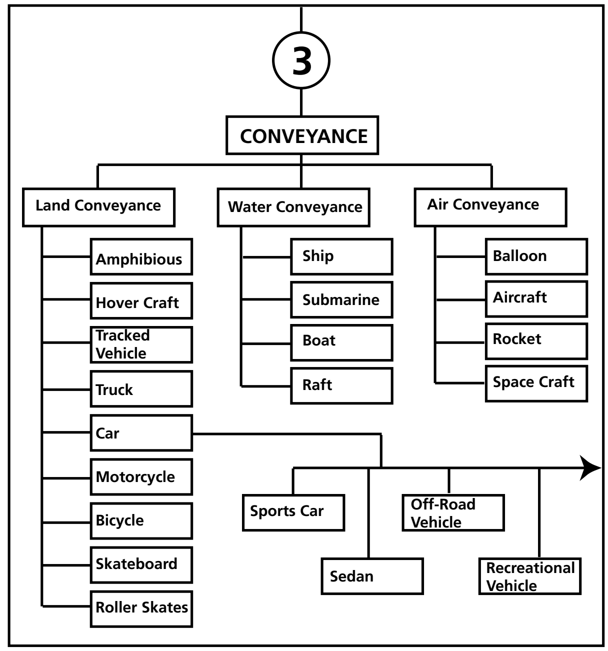


Fig.10: Branch of a typical object model

However, even more important than the characteristics of objects and the notion of inheritance are the relationships that exist between objects. As shown in Fig.12, a car incorporates many components that are in themselves objects. For example, cars typically have engines, steering systems, electric power units, and brake systems. They utilize fuel and often have an air-conditioning system.

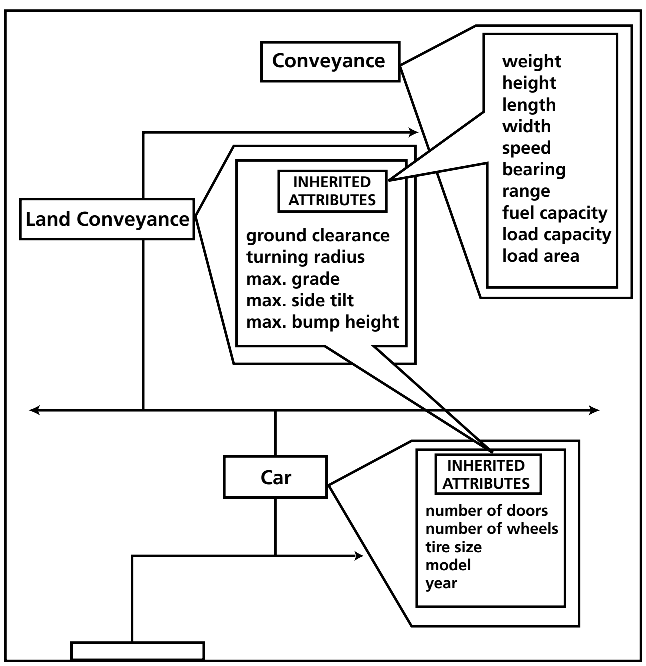


Fig.11: Object model - ***inheritance***

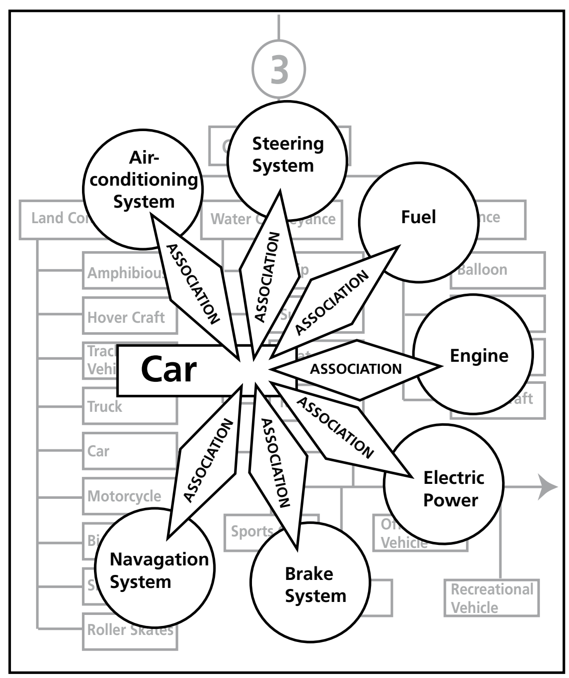


Fig.12: Object model - ***associations***

For several reasons, it is advantageous to treat these components as objects in their own right rather than as attributes of the car object. First, they may warrant further subdivision into parent and child objects. For example, there are several kinds of air-conditioning systems, just as there are several kinds of cars. Second, an air-conditioning system may have associations of its own to other component systems such as a temperature control unit, a refrigeration unit, an air distribution system, and so on. Third, by treating these components as separate objects we are able to describe them in much greater detail than if they were simply attributes of another object. Finally, any changes in these objects are automatically reflected in any other objects that are associated with them. For example, during its lifetime, a car may have its air-conditioning system replaced with another kind of air handling unit. Instead of having to change the attributes of the car, we simply delete the association to the old unit and add an association to the new unit. This procedure is particularly convenient when we are dealing with the association of one object to many objects, such as the wholesale replacement of a cassette tape player with a new compact disk player model in many cars, and so on.

The way in which the construction of such an ontology leads to the representation of information (rather than data) in a digital computer is described in Fig.13, as follows. By international agreement, the American Standard Code for Information Interchange (ASCII) provides a simple binary (i.e., digital) code for representing numbers, alphabetic characters, and many other symbols (e.g., +, -, =, ( ), etc.) as a set of ***0*** and ***1*** digits. This allows us to represent sets of characters such as the sentence ***"Police car crossing bridge at Grand Junction."*** in the computer. However, in the absence of an ontology, the computer stores this set of characters as a meaningless text string (i.e., data). In other words, in the ***data-centric*** realm the computer has no understanding at all of the meaning of this sentence. As discussed previously, this is unfortunately the state of e-mail today. While e-mail has become a very convenient, inexpensive, and valuable form of global communication, it depends entirely on the human interpretation of each e-mail message by both the sender and the receiver.

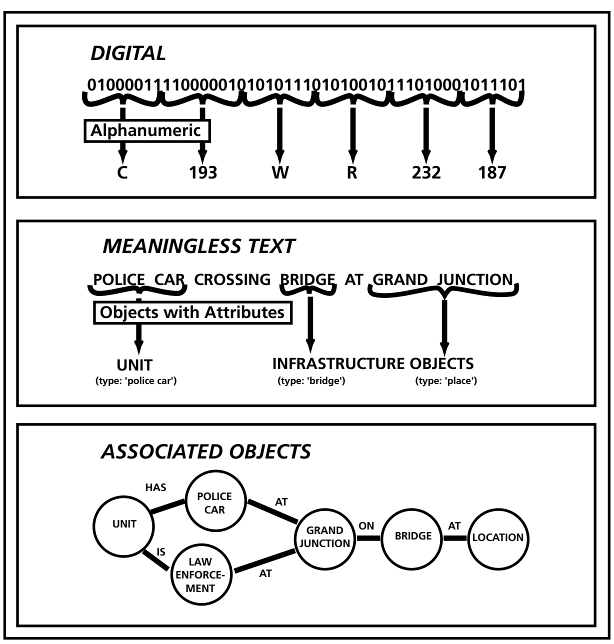


Fig.13: From ***digital*** to ***information***

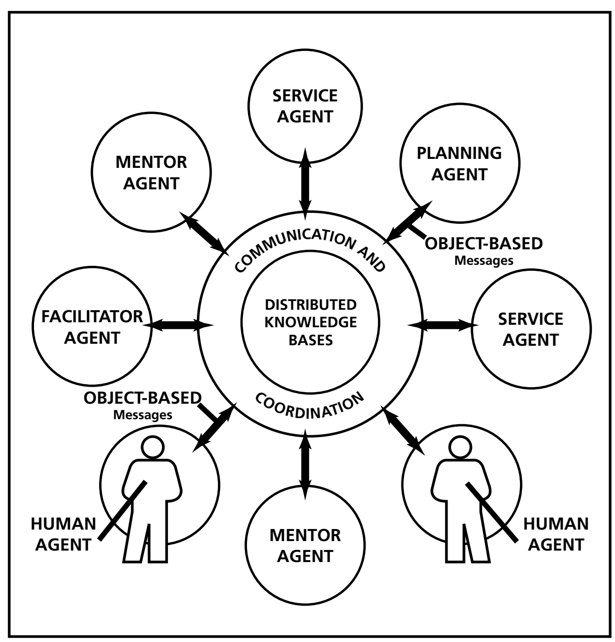


Fig.14: Types of agents

Now, if the ***"Police car crossing bridge at Grand Junction."*** message had been sent to us as a set of related objects, as shown at the bottom of Fig.13, then it should be a relatively simple matter to program computer-based agents to reason about the content of this message and perform actions on the basis of even this limited level of understanding. How was this understanding achieved? In reference to Fig.13, the police car is interpreted by the computer as an instance of a ***car*** object which is associated with a ***civilian organization*** object of kind ***police***. The ***car*** object automatically inherits all of the attributes of its parent object, ***land conveyance***, which in turn inherits all of the attributes of its own parent object, ***conveyance***. The ***car*** object is also associated with an instance of the infrastructure object, ***bridge***, which in turn is associated with a ***place*** object, ***Grand Junction***, giving it a geographical location. Even though this interpretational structure may appear primitive to us human beings, it is adequate to serve as the basis of useful reasoning and task performance by computer-based agents.

The Popular Notion of '*Intelligent Agents*'

Agents that are capable of ***reasoning*** about events, in the kind of ontological framework of ***information*** described above, are little more than software modules that can process objects, recognize their behavioral characteristics (i.e., attributes of the type shown for the objects in Fig.11), and trace their relationships to other objects. It follows, that perhaps the most elementary definition of ***agents*** is simply: "Software code that is capable of ***communicating*** with other entities to facilitate some action". Of course this communication and action capability alone does not warrant the label of ***intelligent***.

The use of the word intelligent is more confusing than useful. As human beings we tend to judge most everything in the world around us in our image. And, in particular, we are rather sensitive about the prospect of ascribing intelligence to anything that is not related to the human species, let alone an electronic machine. Looking beyond this rather emotional viewpoint, one could argue that there are levels of intelligence. At the most elementary level, intelligence is the ability to remember. A much higher level of intelligence is creativity (i.e., the ability to create new knowledge). In between these two extremes are multiple levels of increasingly intelligent capabilities. Certainly computers can remember, because they can store an almost unlimited volume of data and can be programmed to retrieve any part of that data. Whether, computers can interpret what they remember depends on how the data are represented (i.e., structured) in the software.

In this regard, the notion of ***intelligent agents*** refers to the existence of a common language (i.e., the ontological framework of information described earlier) and the ability to ***reason*** about the object characteristics and relationships embodied in the informational structure. Increasing levels of intelligent behavior can be achieved by software agents if they have access to existing knowledge, are able to act on their own initiative, collaborate with other agents to accomplish goals, and use local information to manage local resources.

Such agents may be programmed in many ways to serve different purposes (Fig.14). Mentor agents may be designed to serve as guardian angels to look after the welfare and represent the interests of particular objects in the underlying ontology. For example, a mentor agent may simply monitor the fuel consumption of a car or perform more complex tasks such as helping a tourist driver to find a particular hotel in an unfamiliar city, or alert a platoon of soldiers to a hostile intrusion within a specified radius of their current position in the battlefield (Pohl et al. 1999). Service agents may perform expert advisory tasks on the request of human users or other agents. For example, a computer-based daylighting consultant can assist an architect during the design of a building (Pohl et al. 1989) or a Trim and Stability agent may continuously monitor the trim of a cargo ship while the human cargo specialist develops the load plan of the ship (Pohl et al. 1997). At the same time, Planning agents can utilize the results of tasks performed by Service and Mentor agents to devise alternative courses of action or project the likely outcome of particular strategies. Facilitator agents can monitor the information exchanged among agents and detect apparent conflicts (Pohl 1996). Once such a Facilitator agent has detected a potential non-convergence condition involving two or more agents, it can apply one of several relatively straightforward procedures for promoting consensus, or it may simply notify the user of the conflict situation and explain the nature of the disagreement.

An Information-Centric Transition Architecture

An information-centric decision-support system typically consists of components (or modules) that exist as clients to an integrated collection of services. Incorporating such services, the information-serving collaboration facility (Fig.15) communicates to its clients in terms of the real world objects and relationships that are represented in the information structure (i.e., the underlying ontology). The software code of each client includes a version of the ontology, serving as the common language that allows clients to communicate ***information*** rather than data.

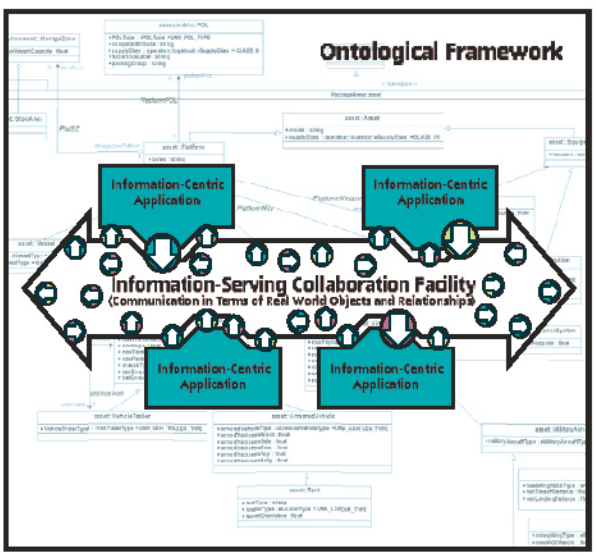


Fig.15: Information-centric interoperability.

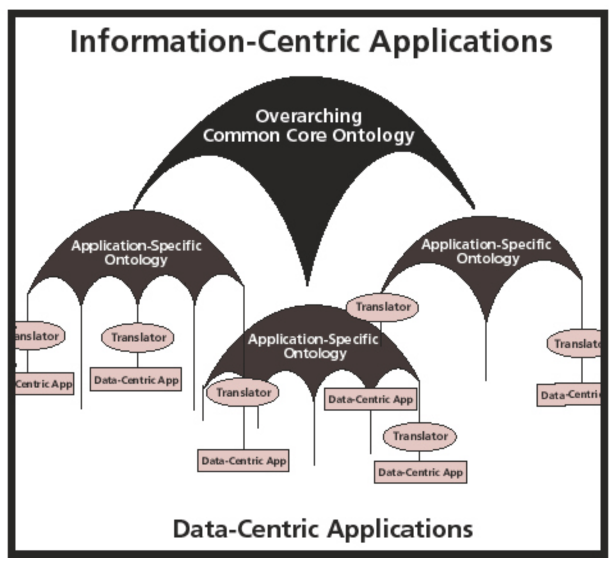


Fig.16: Transitioning to an information-centric architecture.

To reduce the amount of work (i.e., computation) that the computer has to accomplish and to minimize the volume of information that has to be transmitted within the system, two strategies can be readily implemented. First, each client can register a standing request with the collaboration facility for the kind of information that it would like to receive. This is referred to as a subscription profile, and the client has the ability to change this profile dynamically during execution if it sees cause to ask for additional or different information. For example, after receiving certain information through its existing subscription profile, a Mentor agent representing a squad of Marines may decide to request information relating to engagement events in a different sector of the battlefield, henceforth. By allowing information to be automatically ***pushed*** to clients, the subscription service obviates the need for database queries and thereby greatly reduces the amount of work the computer has to perform. Of course, a separate query service is also usually provided so that a client can make one-time requests for information that is not required on a continuous basis.

The second strategy relates directly to the volume of information that is required to be transmitted within the system. Since the software code of each client includes a version of the ontology (i.e., common language) only the changes in information need to be communicated. For example, a Mentor agent that is watching over a squad of Marines may have more than 100 objects included in its subscription profile. One set of these objects represents an enemy unit and its warfighting capabilities. If this unit changes its position then in reality only one attribute (i.e., the location attribute) of one object may have changed. Only the changed value of this single object needs to be transmitted to the Mentor agent, since as a client to the collaboration facility it already has all of the information that has not changed.

How does this ***interoperability*** between the collaboration facility and its clients translate into a similar interoperability among multiple software applications (i.e., separate programs dealing with functional sequences in related domains)? For example, more specifically, how can we achieve interoperability between a tactical command and control system such as IMMACCS (Pohl et al. 1999) and a logistical command and control system such as SEAWAY (Wood et al. 2000)?

Since both of these software systems are implemented in an information-centric architecture, the underlying information representation can be structured in levels (Fig.16). At the highest level we define notions, concepts and object types in general terms. This overarching common core ontology sits on top of any number of lower level application specific ontologies that address the specific bias and level of granularity of the particular application domain. For example, in the core ontology an 'aircraft' may be defined in terms of its physical nature and those capabilities that are essentially independent of its role in a particular application domain. In the tactical domain this general description (i.e., representation) of an 'aircraft' is further refined and biased toward a warfighting role. In other words, the IMMACCS application sees an aircraft as an airborne weapon with certain strike capabilities. SEAWAY, on the other hand, sees an aircraft as an airborne mobile warehouse capable of transporting supplies from one point to another.

The interoperability capabilities of an information-centric software environment will also allow agents in one application to notify agents in other applications of events occurring in multiple domains. For example, the Engagement Agent in the tactical IMMACCS application is able to advise appropriate agents in the logistical SEAWAY application whenever a Supply Point ashore is threatened by enemy activity. This may result in the timely rescheduling or redirection of a planned re-supply mission. The agents are able to communicate across multiple applications at the information level through the common language of the ontological framework. Similarly, the SEAWAY application is able to rely on the ICODES (Pohl et al. 1997) ship load planning application to maintain in-transit cargo visibility, down to the location of a specific supply item in a particular container on-board a ship en-route to the sea base.

One might argue that this is all very well for newly developed applications that are by design implemented in an ***information-centric*** architecture, but what about the many existing ***data-centric*** applications that all perform strategic and indispensable functions? These existing legacy applications constitute an enormous investment that cannot be discarded overnight, for several reasons. First, they perform critical functions. Second, it will take time to cater for these functions in the new decision-support environment. Third, at least some of these functions will be substantially modified or eliminated as the information-centric environment evolves.

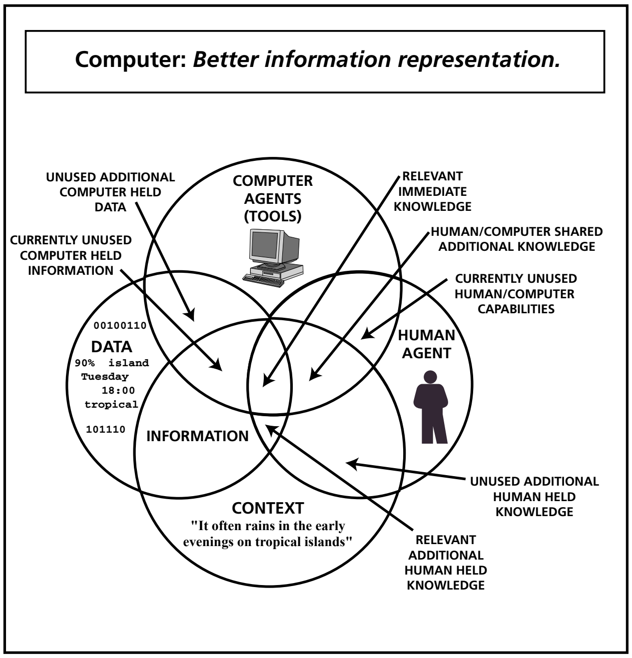
As shown in Fig.16, data-centric applications can communicate with information-centric systems through translators. The function of these translators is to map those portions of the low level data representation of the external application that are important to the decision-making context, to the ontology of the information-centric system. Conversely, the same translator must be capable of extracting necessary data items from the information context and feed these back to the data-centric application. Typically, as in the case of IMMACCS (Pohl et al. 1999), this translation capability is implemented as a universal translator that can be customized to a particular external application. The translator itself, exists as a client to the information-serving collaboration facility (Fig.15) of the information-centric system and therefore includes in its software code a version of the ontology that describes the common language of that system.

Conclusion

While the capabilities of present day computer-based agent systems are certainly a major advancement over data-processing systems, we are only at the threshold of a paradigm shift of major proportions. Over the next several decades, the context circle shown in Fig.17 will progressively move upward into the computer domain, increasing the sector of "relevant immediate knowledge" shared at the intersection of the human, computer, data, and context domains. Returning to the historical evolution of business intelligence described previously in reference to Figs. 6, 7 and 8, the focus in the early 2000s will be on information management as opposed to data-processing (Fig.18). Increasingly, businesses will insist on capturing data as information through the development of business enterprise ontologies and leverage scarce human resources with multi-agent software capable of performing useful analysis and pattern-detection tasks.

An increasing number of commercial companies are starting to take advantage of the higher level collaborative assistance capabilities of computers to improve their competitive edge and overcome potential customer service difficulties. A good example is the timely detection of the fraudulent use of telephone credit card numbers. Telephone companies deal with several million calls each day, far too many for monitoring by human detectives. Instead, they have implemented intelligent computer software modules that monitor certain information relating to telephone calls and relate that information to the historical records of individual telephone users. The key to this capability is that telephone call data such as time-of-day, length of call, origin of call, and destination are stored in the computer as an information structure containing data objects, relationships, and some attributes for each data object. For example, the data 'Columbia' may have the attributes international, South America, uncommon telephone call destination, attached to it. In addition, relationships are established dynamically between 'Columbia' the telephone number of the caller, the telephone number being called, the time-of-day of the call, and so on. The result is a network of objects with attributes and relationships that is very different from the data stored in a typical commercial data-mart. This network constitutes information (rather than data) and allows hundreds of software ***agents*** to monitor telephone connections and detect apparent anomalies. What is particularly attractive about this fairly straightforward application of ***information-centric*** technology, is that the software ***agents*** do not have to listen in on the actual telephone conversations to detect possibly fraudulent activities.

However, from the telephone company's point of view this use of expert ***agents*** saves millions of dollars each year in lost revenues.



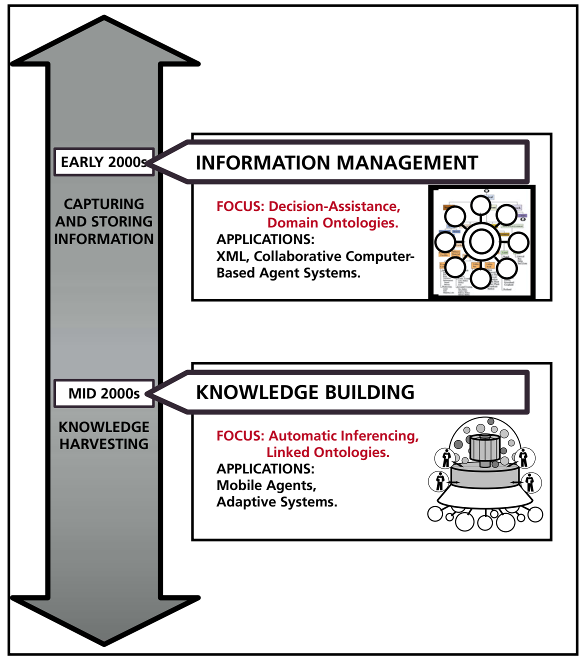


Fig.17: Evolving human-computer partnership Fig.18: Evolution of business intelligence (D)

Toward the mid 2000s, we can expect some success in the linking of such ontologies to provide a virtually boundless knowledge harvesting environment for mobile agents with many kinds of capabilities. Eventually, it may be possible to achieve virtual equality between the information representation capabilities of the computer and the human user. This virtual equality is likely to be achieved not by the emulation of human cognitive capabilities, but rather, through the skillful combination of the greatly inferior artificial cognitive capabilities of the computer with its vastly superior computational, pattern-matching and storage facilities.

References

Denis S. (2000); 'Numbers'; Intelligent Enterprise, April 10 (pp. 37-44).

Ginsberg M. (1993); 'Essentials of Artificial Intelligence'; Morgan Kaufmann, San Mateo, California.

Horstmann C. and G. Cornell (1999); 'Core Java'; Vol. 1 and 2, Sun Microsystems Press, Prentice Hall, Upper Saddle River, New Jersey.

Humphries M., M. Hawkins and M. Dy (1999); 'Data Warehousing: Architecture and Implementation'; Prentice Hall, Upper Saddle River, New Jersey.

Pedersen T. and R. Bruce (1998); 'Knowledge Lean Word-Sense Disambiguitization'; Proceedings 5th National Conference on Artificial Intelligence, July, Madison WI.

Pohl J., M. Porczak, K.J. Pohl, R. Leighton, H. Assal, A. Davis, L. Vempati and A. Wood, and T. McVittie (1999); ‘IMMACCS: A Multi-Agent Decision-Support System’; Technical Report, CADRU-12-99, CAD Research Center, College of Architecture and Environmental Design, Cal Poly, San Luis Obispo, California, August.

Pohl J., A. Chapman, K. Pohl, J. Primrose and A. Wozniak (1997); 'Decision-Support Systems: Notions, Prototypes, and In-Use Applications'; Technical Report, CADRU-11-97, CAD Research Center, Design Institute, College of Architecture and Environmental Design, Cal Poly, San Luis Obispo, California, January.

Pohl J., L. Myers, A. Chapman and J. Cotton (1989); 'ICADS: Working Model Version 1'; Technical Report, CADRU-03-89, CAD Research Center, Design Institute, College of Architecture and Environmental Design, Cal Poly, San Luis Obispo, California.

Pohl K.(1996); ‘KOALA: An Object-Agent Design System’; in Pohl J. (ed.) Advances in Cooperative Environmental Design Systems, Focus Symposium: International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, Aug.14-18 (pp.81-92).

Stroustrup B. (1987); ‘The C++ Programming Language’; Addison-Wesley, Reading, Massachusetts.

Verity J. (1997); ‘Coaxing Meaning Out of Raw Data’; Business Week, June 15.

Wood A., K. Pohl, J. Crawford, M. Lai, J. Fanshier, K. Cudworth, T. Tate, H. Assal, S. Pan and J. Pohl (2000); ‘SEAWAY: A Multi-Agent Decision-Support System for Naval Expeditionary Logistic Operations’; Technical Report, CDM-13-00, CDM Technologies, Inc., San Luis Obispo, California, December.

Office of Naval Research Logistics Program

Third Annual Decision Support Workshop "Continuing the Revolution in Military Affairs"

06 June 2001

Dr. Phillip B. Abraham
ONR 362
703-696-4307
abrahaph@onr.navy.mil

OVERVIEW

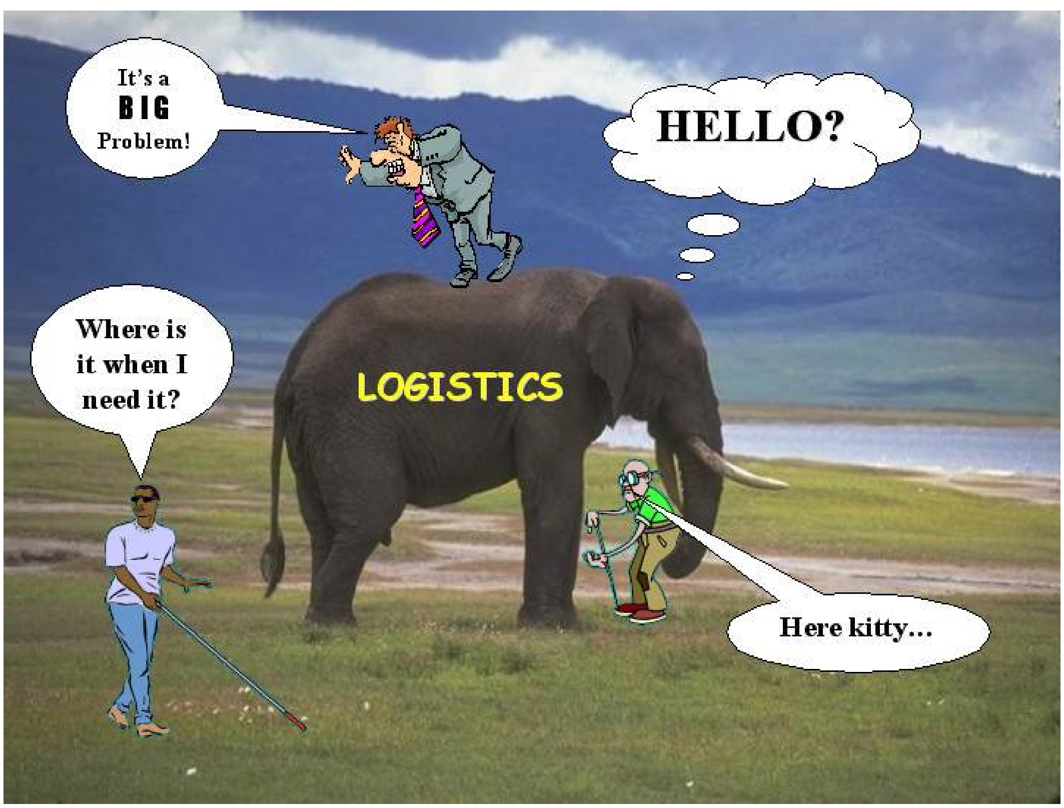
The Role of Logistics in the Revolution in Military Affairs

- Introduction
- Logistics: What is it?
- Decision Support Systems: Why?
- Vision of Logistics for the 21st Century
- Summary

INTRODUCTION

It has been stated, possibly by Napoleon, that an army marches on its belly. Of course, it was understood by everybody that "belly" signified all that an army needs for a campaign or a mission. And this is perhaps how the concept of Logistics has entered the military conciousness. But once entrenched in the military, this concept has penetrated into the civilian world. This has not necessarily been beneficial to the understanding of what Logistics is, or should be. Vulgarization of a concept leads to it becoming a buzz word, and in many instances with little understanding of the complexities pertaining to that concept. I believe that this is the case for Logistics. In this talk I wish to to present an analysis of Logistics that will emphasize the overarching role that Logistics plays in military affairs. I want to preface my presentation with an apology to those members of this audience who are logisticians by profession (or have dealt with logistics throughout their respective careers). I nevertheless hope that even these persons will find some fresh insights in my discussion of what Logistics is all about (my first topic). My next topic is a discussion of Decision Support Systems , which includes a description of their role and actual implementation, in particular the modern approach to their construction. I continue with a vision of Logistics for the 21st century. Among other items, this section describes the various projects that the ONR Logistics Program is actively supporting at present and some planned projects as well. I conclude with a general summary.

What *is* logistics?



What ***is not*** logistics?

Logistics encompasses the whole universe as perceived and understood by humans.

"All human plans and actions ultimately translate into logistic demands and actions."

Goal of Logistics

OPERATIONAL READINESS

ANY TIME -- ANY PLACE

Operational Readiness

WHAT
- Platforms: Surface Ships, Subs, Aircraft
- Systems: Weapons, Machinery, Electric/Electronic Sensors, Budget, Inventory, Personnel, Training
- Shore Facilities: In and Out of Theater
- Processes: Actions/Procedures
- Environment and Quality of Life

HOW
- Asset Readiness: Location (RFID tags), State of Health (via appropriate sensors)
- Decision-Making: Readiness as function of mission via collaborative agents

Logistics Does Not Stop Here

WHAT implies the existence of:

- Supply sources (manufacture/distribution centers)
- Resources (financial, human, other)

HOW implies the existence of:

- Tangible resources required in the supply chain of the WHAT (e.g., transportation assets, piers, marshalling yards, cranes, etc.)
- Intangibles (processes, procedures, algorithms, human expertise, intuition, and determination, etc.)

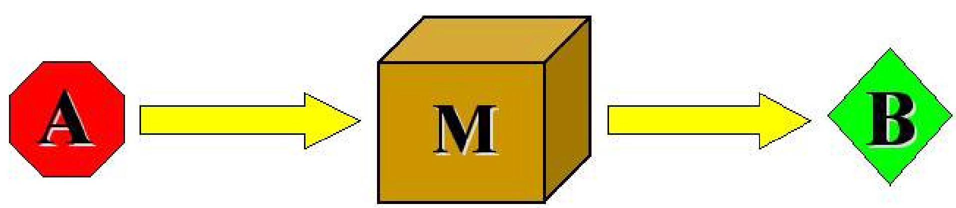
What Is Difficult About Logistics?

ANATOMY OF A LOGISTIC EVENT

PERCEPTIONS ABOUT LOGISTIS

AN ANALYSIS OF THE CONVENTIONAL OR

MUNDANE VIEW OF THE LOGISTICS TASK



RIGHT? NOT QUITE!

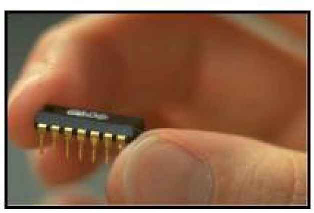
1. HOW DO YOU TRANSPORT (I.E., WHAT ARE YOUR MEANS OF TRANSPORTATION)?

ARE TRANSPORTATION ASSETS READY?

2. WHERE DOES M COME FROM?

IS IT THERE AND READY TO GO?

3. WHO BUILT, SOLD, STORED M
AND BROUGHT IT TO A ?



4. IS M THE RIGHT THING FOR THE MISSION?

5. WHEN (THE RIGHT) M IS USED UP, IS THERE ENOUGH OF M FOR THE MISSION OR THERE IS A NEED TO REPLENISH A ? AND WHERE FROM?

6. A AND B ARE NOT NECESSARILY STATIONARY SO TAKE THIS INTO CONSIDERATION.

7. TIME IS OF THE ESSENCE.

WE MUST BE READY.

The New York Times | The Washington Post Online | The Boston Globe

Report: ***Pentagon System Needs Fixing*** by Pauline Jelinek, AP Writer

Tuesday, May 22, 2001; 6:24 p.m. EDT

WASHINGTON — The Pentagon system for dispensing spare parts for airplanes, tanks, and other equipment is broken and officials aren't sure how to fix it.

At least 154,000 times a year, a military mechanic takes a part from one airplane and puts it on another because a new spare part is not on hand, says a preliminary report by the General Accounting Office.

"The practice is called 'cannibalization' and it's eating into ... **readiness**," Rep. Christopher Shays, R-Conn., said at a House subcommittee hearing where the report was discussed Tuesday.

Cannibalization is also a waste of time and money – costing 1 million extra work hours a year – and it risks damaging the aircraft as well as the morale of mechanics doing the work, said others who testified.

The San Diego Union-Tribune. | Chicago Tribune chicagotribune.com | Los Angeles Times latimes.com

SUMMARY OF LOGISTICS

- Design
- Manufacture / Acquisition
- Transportation
- Supply Chain / Replenishment
- Maintenance / Life Cycle
- Technology Refresh
- Mission Planning
- Knowledge Bases
- Decision Making

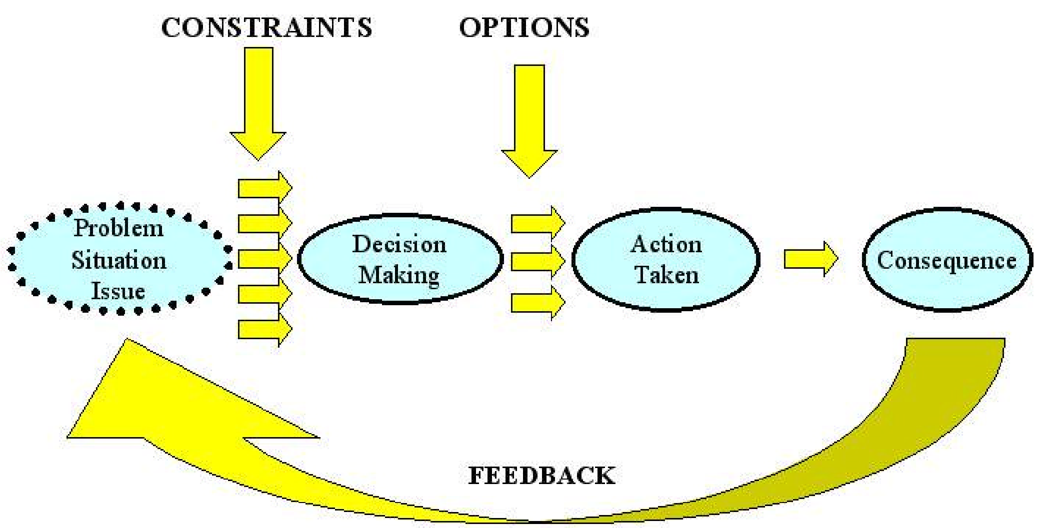
DECISION SUPPORT SYSTEMS

- **INTRODUCTION**
- **DECISION MAKING PROCESS**
- **DECISION MAKING TECHNOLOGY**
- **DECISION SUPPORT SYSTEMS**
- **DECISION MAKING FOR THE 21st CENTURY**
- **SUMMARY**

INTRODUCTION

- Humans make decisions in response to external/internal stimuli.
- The decisions made can be conscious or subconscious.
- To make decisions, humans need and make use of the knowledge they possess.
- The decisions made are influenced by limitations of knowledge (i.e., uncertainty) and random changes in the contingencies requiring decisions.

The Process of Decision Making



DECISION MAKING TECHNOLOGY

- •Intelligent agents
  - •Knowledge Acquisition
  - •Agent Creation
- •Agent Collaboration
- •Agent Profiles
  - •Monitoring Agents
  - •Learning Agents
  - •Mentoring Agents

DECISION SUPPORT SYSTEMS (DSS)

MINIMAL REQUIREMENTS

- APPLICABLE TO COMPLEX LARGE SCALE PROBLEMS
- SOPHISTICATED, YET IMPLEMENTABLE
- ROBUSTNESS
- PROVIDE OPTIONS RAPIDLY
- SELF-CONSISTENCY
- DSS BASED ON AGENTS THAT CREATE AGENTS
- REASONABLE COST

21st CENTURY APPLICATIONS OF AGENT-BASED DECISION SUPPORT SYSTEMS (DSS)

- **The Military**
- **Civilian Government Organizations**
- **Architecture**
- **Industry**
- **Jurisprudence: Agents monitor & alert when conflicts among laws & rules occur.**
- **Medicine: Diagnostics & treatment, patient monitoring, pharmaceutical industry**
- **Basic & Applied Research: Taxonomy of the fauna & flora, bacteriology, microbiology**
- **Robotics: A robot is an agent**
- **Education & Training**
- **Physics & Mathematics**
- **Esthetics & Ethics: Standards of beauty & of conduct as agents**
- **Risk Management**
- **Other: Human imagination will come up with unforeseen uses**

DECISION MAKING FOR THE 21st CENTURY

- ***ANALYZE*** systems, processes, organizations, missions into reasonable constituent parts.
- REPEAT the procedure in each of these parts, then repeat it in each of their constituents, as necessary.
- ESTABLISH layers of constituents with hierarchical ranking among layers, and each constituent represented by a supervisor reporting to a higher level one.
- ESTABLISH lines of communication within and among the layers, each layer represented by a supervisor.
- ENDOW each unit of a constituent in a layer with appropriate ***DECISION MAKING TOOLS***, and do the same for each of the supervisors in the hierarchical chain, all the way to the top of the pyramid where the ultimate supervisor resides.
- For each unit, constituent and layer ASSEMBLE the ***KNOWLEDGE BASE*** specific to its function.

DECISION MAKING SUMMARY

- DECISIONS ARE MADE BY EVERYBODY, EVERYWHERE, ALL THE TIME
- CONSEQUENCES OF ACTIONS DUE TO DECISIONS MADE LEAD TO NEW SITUATIONS REQUIRING FURTHER DECISION MAKING
- COMPLEX SITUATIONS DEMAND COMPLEX DECISION SUPPORT SYSTEMS
- SUPPORT SYSTEMS MUST MEET MINIMAL REQUIREMENTS TO BE USEFUL
- THE DECISION SUPPORT PROCESS MUST BE SUFFICIENTLY TRANSPARENT TO ALLOW THE SCRUTINY OF USERS AND PEERS

Vision of Logistics for the 21st Century

21st Century Logistics

- Decision Making
- Integration of All Aspects of Fleet Operations: Mission Planning, Logistics Assets, Total Operational Readiness
- Total Asset Tracking and Management
- Rapid Autonomous Replenishment of Lean Inventory
- Workload Reduction
- Large-Capacity Communication Links
- Continuous Monitoring of Mission Progress

ONR Initiatives for the 21st Century

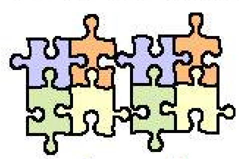
- Integration of Fleet Operations
  - SILS, *STILS, Collaborative Logistics Planning*
- Decision-Making Support
  - CIAT, SEAWAY, ACCOT, NAWMS
- Total Asset Tracking with *State-of-Health Sensors*
  - NAV, Sensing and Diagnostics
- Workload Reduction
  - Maintenance, Automation, Robotics
- Continuous Monitoring of Mission Progress
  - SEAWAY, ACCOT, NAWMS

Projects in Italics: Planned

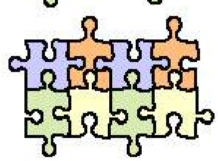
Integration of Operations

VARIETIES OF INTEGRATION

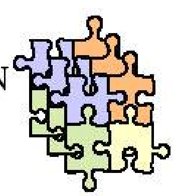
- PARTIAL INTEGRATION



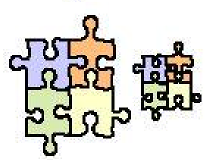
- FULL INTEGRATION



- OVERLAPPING INTEGRATION
  (Duplication)



- MISINTEGRATION



WHAT IS INTEGRATION?

The process of linking autonomous constituents to act together, in their own special expertise, toward a preset common goal.

"If you've got the time, we've got the beer!"

HOW IS INTEGRATION ACHIEVED?

So far, no universal answer exists...

SHIPBOARD INTEGRATION OF LOGISTIC SYSTEMS (SILS)

SYSTEMS

PLATFORM, MACHINERY,
ELECTRONICS, WEAPONS, PROCESSES/PROCEDURES,
INVENTORY, BUDGET,
PERSONNEL, TRAINING

SENSORS

Adapted to
Individual Systems

DIAGNOSTICS/PROGNOSTICS

Physical Principles
Neural Networks/
Case Based Reasoning
Historic Data
Trend Analysis

RECORD KEEPING

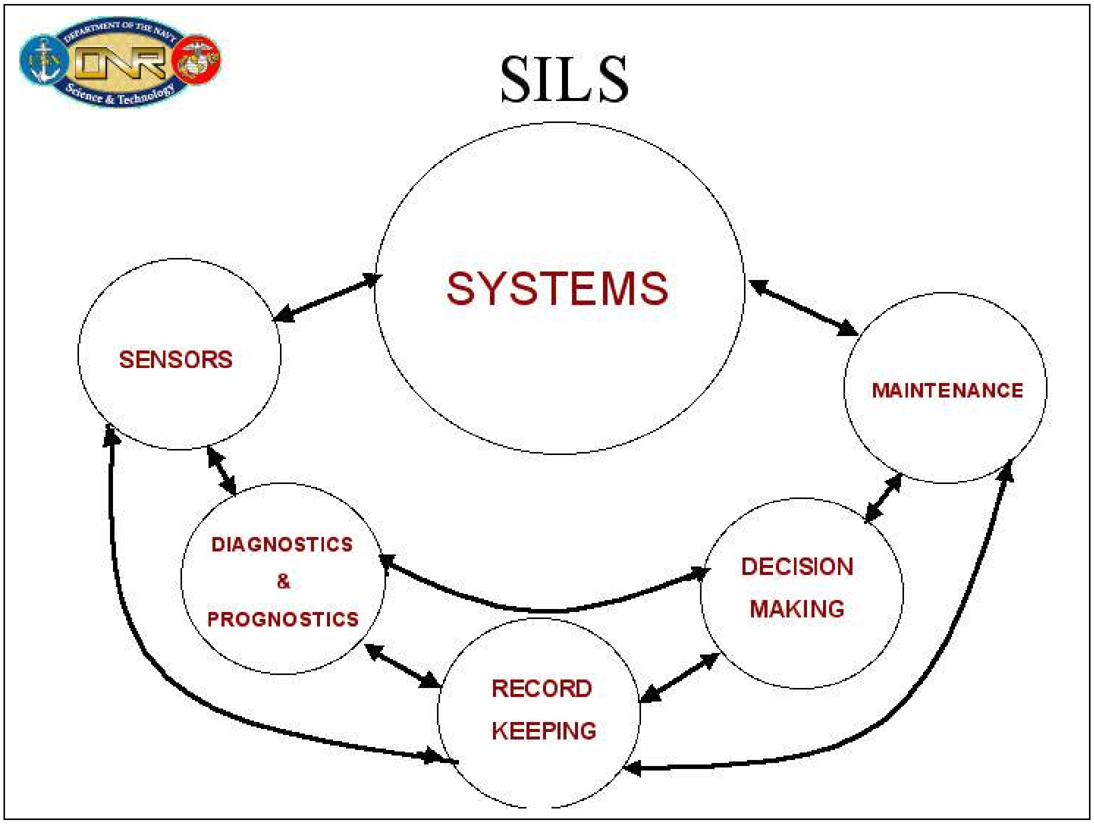
Data Bases
Creation & Update

MAINTENANCE

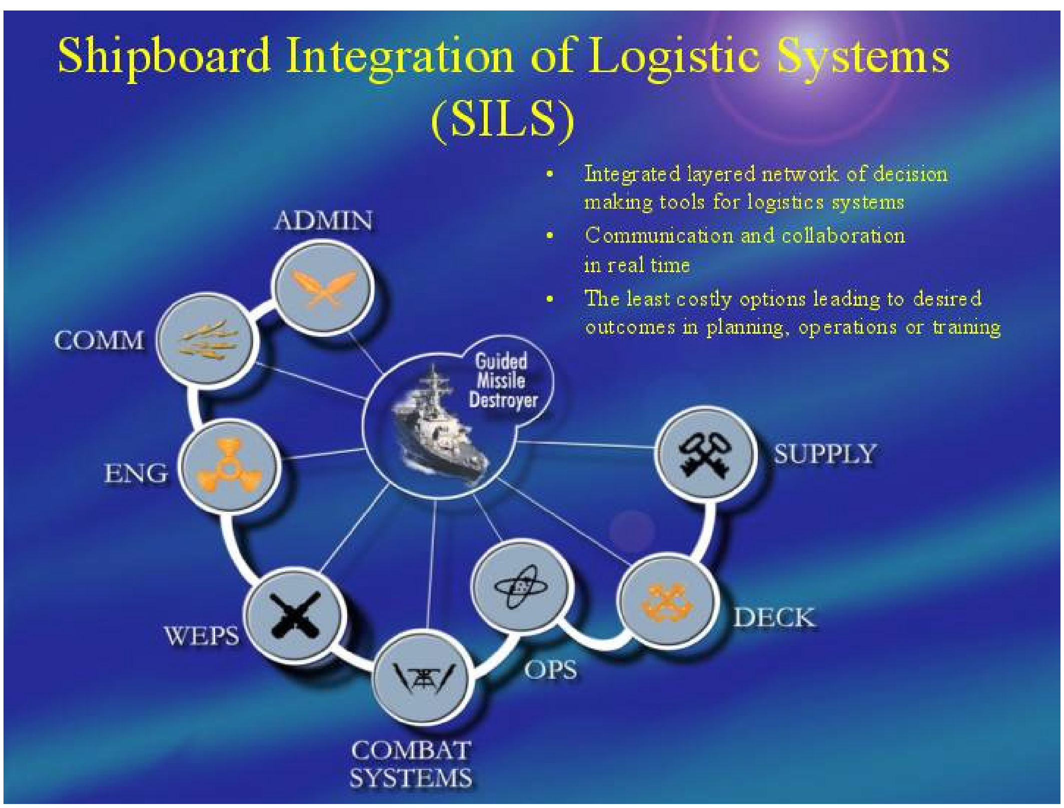
Repair/Replace
Modify Process/Procedure
Train/Retrain
IETMs

DECISION MAKING

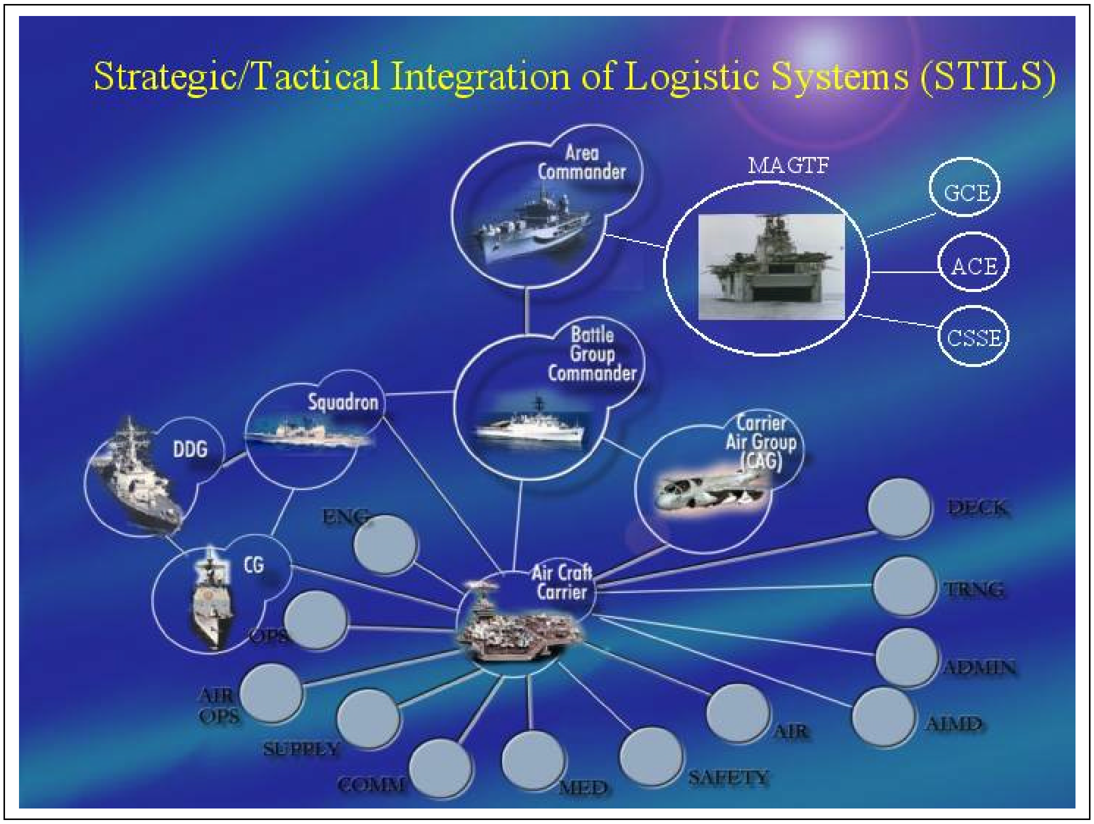
Support tools
Expert Agents
Platform Mission
Options
Humans in Loop



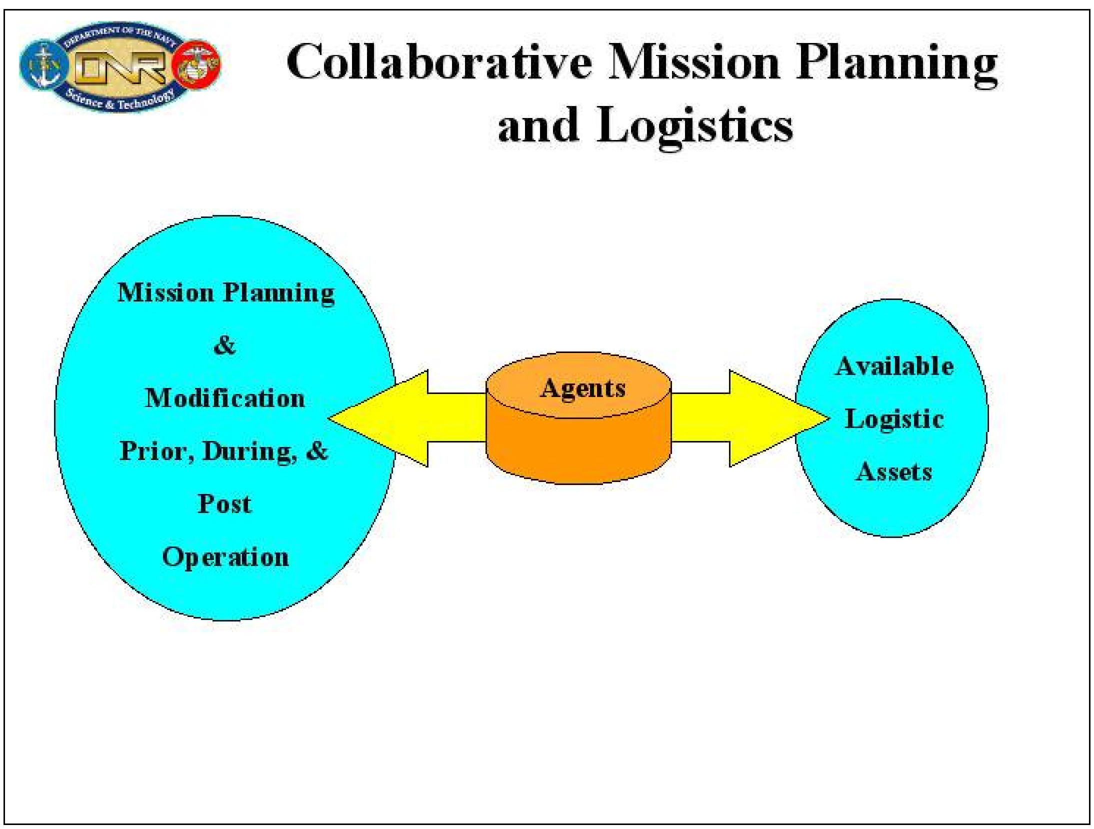
SILS
SYSTEMS
SENSORS
MAINTENANCE
DIAGNOSTICS
&
PROGNOSTICS
DECISION
MAKING
RECORD
KEEPING



Shipboard Integration of Logistic Systems (SILS)
Integrated layered network of decision making tools for logistics systems
Communication and collaboration in real time
The least costly options leading to desired outcomes in planning, operations or training
ADMIN
COMM
ENG
WEPS
COMBAT SYSTEMS
OPS
DECK
SUPPLY
Guided Missile Destroyer



Strategic/Tactical Integration of Logistic Systems (STILS)
Area Commander
MAGTF
GCE
ACE
CSSE
Battle Group Commander
Squadron
DDG
Carrier Air Group (CAG)
DECK
ENG
CG
Air Craft Carrier
TRNG
OPS
ADMIN
AIR OPS
AIMD
AIR
SUPPLY
SAFETY
COMM
MED



Collaborative Mission Planning and Logistics
Mission Planning & Modification Prior, During, & Post Operation
Agents
Available Logistic Assets

General Summary

Expectations from the RMA of the 21st Century

- LOGISTICS, as the backbone of all military organizations and their operations, must be considered as the most critical constituent in any change of the Armed Forces mandated by the civilian policy makers.
- Refined Decision Support Systems should be used to shape these changes so as to make them logistically feasible – this includes the design of new hardware, processes, procedures, and training.
- Study the process of integration in order to facilitate its use in all needed contexts.
- Institute widespread training of the Armed Forces in the applications of agent technology.
- Accelerate the transition of new hardware and processes to the Armed Forces.
- Experimentation and counter-experimentation

Acronyms

CIAT: Collaborative Infrastructure Assessment Tool (Naval Stations Operations)

SEAWAY: Collaborative Management of Land Operations and the Sea-based Support

ACCOT: Aircraft Carrier Collaborative Operations Tool (Aircraft Mission Manager)

NAWMS: Naval Aviation Weapons Management System

SILS: Shipboard Integration of Logistic Systems

STILS: Strategic/Tactical Integration of Logistic Systems

NAV: Naval Asset Visibility

Keynote Address

Rear Admiral Jay M. Cohen

Chief of Naval Research
United States Navy

(***Editor s Apology:*** *Unfortunately due to equipment failure RAdm Cohen s address could not be recorded during the Workshop. With his kind permission we have included in these proceedings a copy of his address to the House Armed Services Committee of the US Congress, delivered on the 26th of June, 2001.)*

Mr. Chairman, distinguished members of the subcommittee, thank you for this opportunity to discuss the Department of the Navy s Science and Technology Program.

When Admiral Clark assumed the watch from Admiral Jay Johnson last summer, he said that our people were our first priority.˚ His Marine Corps counterpart, General Jones, is equally committed to doing everything we can for his few and proud Marines.

One of the most important ways we can keep our people and recruit more like them is to give them the best working conditions possible.˚ While the bedrock of our Navy and Marine Corps is good leadership, technology is the foundation that rests on that bedrock.˚ Admiral Clark has directed me, as Chief of Naval Research, to make science and technology work for our people in the Fleet.˚ And since I also wear the hat of Assistant Deputy Commandant (Science and Technology) for the Marine Corps, I answer to the same marching orders from General Jones make science and technology work for the Marine.˚ So I will couch quite a bit of my testimony today in terms of what we re doing to deliver capabilities for Sailors and Marines.˚ I think we have a great record, a sound process, and a terrific future.

As Chief of Naval Research, I want to protect our warfighters from technological surprises, while giving them the tools to inflict surprises on our adversaries.˚ The business of surprise is especially important today.˚ The threats we face are too variable to yield to the clear responses available during the Cold War.˚ I would like to draw out one fundamental lesson from the Cold War and other more recent situations as uncertainty increases, options increase in value.˚ My priorities electric warship, missile defense/space, human factors, environment, and efficiency will offer out of the box capability options; it s my job to give the Secretary, and the CNO, the Commandant, technology options they can exercise at need.

Our science and technology strategy balances long-term interests with short-term needs. The health of our science and technology base our ability to discharge our national naval responsibilities, to remain a smart buyer of science and technology, and to get capabilities into the hands of the operating forces ultimately depends upon a balanced portfolio from basic research through advanced technology development and manufacturing technology.

I especially look forward to incorporating Secretary Gordon England s industry perspective on maximizing the Department of the Navy s precious technology investments.˚

For the next Navy and Marine Corps, we are concentrating our science and technology investment into focused programs designed to provide a critical mass of support that will yield Future Naval Capabilities (FNCs).˚ I recently restructured the program to combine overlapping efforts, and I added two programs Electric Warship and Combat Vehicles Technology (which will focus on bringing the advantages of electrical technologies to the naval warfighters), and Littoral Combat and Force Projection (which includes both combat and expeditionary logistics capabilities), which will focus on Marine Corps requirements in projecting power from the beach in-land.˚ The other ten FNCs (in no priority order) are:

Autonomous Operations will focus on dramatically increasing the performance and affordability of Naval organic unmanned vehicle systems;

Capable Manpower will focus on selection and training to provide fully prepared Sailors and Marines through human-centered hardware and systems;

Knowledge Superiority and Assurance will focus on issues of connectivity and knowledge superiority for distributed Naval forces to ensure common situation understanding, increased speed of command, interoperability, and dynamic distributed mission planning and execution across all echelons;

Littoral Antisubmarine Warfare will provide effective capability to detect, track, classify and neutralize anti-access threats imposed by enemy submarines, in support of power projection ashore;

Missile Defense will focus S&T necessary to detect, control, & engage projected theater ballistic & cruise missiles as well as enemy aircraft threats;

Organic Mine Countermeasures will focus on an organic MCM capability to shorten the MCM tactical timeline and eliminate the need for manned operations in a minefield;

Platform Protection strives to win or avoid engagements with evolving threats either in-stride or while engaged in projecting power from the sea;

Time Critical Strike will focus S&T that provides a substantial reduction in the engagement timeline against time critical mobile targets, theatre ballistic missiles, weapons of mass destruction, C4I centers and armored vehicles;

Total Ownership Cost Reduction seeks to significantly decrease costs associated with acquisition, operation and support and to develop methods to accurately predict costs and assess return on investment; and,

Warfighter Protection will focus on protecting Warfighters to reduce casualties in the emerging Expeditionary Maneuver Warfare battlespace.

I have directed my people to get close to the Fleet and the Force, to be alert to their needs and swift to respond to them.˚ We are working to enhance their quality of service.˚ As we connect better with our customers the operating Fleet and Force we are undertaking some novel initiatives to reduce the cycle time of our technologies.˚ I have established a program I call Swamp Works .˚ This takes high-risk, high-payoff technologies, puts the right stakeholders together, and gets a product into the hands of the operators who need it.˚ Swamp Works efforts are intended to be technically risky I anticipate a 90% failure rate because leap-ahead work is always technically risky.˚

Force protection crosses all technologies.˚ New materials for hull protection, advanced sensors, next generation decision support systems, autonomous platforms, and, ultimately, directed energy weapons all of these are technological responses to the asymmetric threats our forces encounter as they remain forward deployed.

Another priority I mentioned is human factors and quality of service.˚ Our young people will join and stay with us if we give them meaningful and challenging missions, and if we give them the means to accomplish those missions.˚ The biggest morale-killers on a ship can be those repetitious, labor-intensive, dirty maintenance jobs that have to be done.˚ Naval science and technology offers solutions: coatings that don t have to be scraped and chipped; fault diagnostics that tell you when a bearing is about to fail; condition-based maintenance that saves time and resources.˚ And the smart people we have in the Fleet today deserve to work with systems that are engineered with the human being in mind.˚ Human-centric systems, because the system is made for the Sailor and Marines not vice-versa.˚ These include embedded training that helps Sailors and Marines work smarter, stay proficient, and learn new skills.˚ There is also no greater satisfaction in Sailors and Marines working lives than accomplishing their mission and getting home to their loved ones.

Additionally, we are working to field hearing protection systems and vaccines to keep our Sailors and Marines healthy.˚ We are working on more effective firefighting tools and techniques.˚ We continue to work on environmentally friendly technologies such as the active noise cancellation program that may help our fighter jets to coexist with the ever-increasing civilian population around our bases.

Our laboratories are vital for our Nation s development of future, essential warfighting capabilities.˚ The labs perform a variety of related functions associated with the development of new war-fighting systems and the insertion of new technology into legacy systems.˚ The Navy is working with Department of Defense in developing a process to implement the authority for direct hiring that Congress provided for the labs.˚ I support this authority and believe it will improve the workforce and the efficiency of our laboratories.˚ I will be happy to report back to you our progress in this matter.˚ I hope you will visit our world class corporate laboratory, the Naval Research Laboratory, here in Washington, DC.

With the assistance and support of the Vice Chief of Naval Research, Brigadier General William Catto, who is with me here today, I focus on the Navy and Marine Corps of today, tomorrow and after-next (the one that will fight and win battles in 2020 and beyond).˚ I have given examples above of initiatives in progress for today and tomorrow.˚ The Navy and Marine Corps after-next will be based on discoveries just being made today.˚ To ensure we get the technology and development concepts right, a robust cycle of innovation, validated by experimentation that leads to transformation, must continue.˚ It is a process without end; new technologies evolve, new ideas are born, new innovations must be experimented with, resulting in further transformation.˚ It is a process as old as the Navy and Marine Corps, and as relevant as the need for a strong national defense today, tomorrow and always.˚

The United States has a Navy and Marine Corps second to none in the world, thanks to America s investment in science and technology.˚ I have committed to a science and technology program that ensures our technological superiority continues in this new century and a program that has the Sailor and Marine at its center.

Insights into Optimum TTPs/SOPs for Battalion, Regimental, and Brigade Command and Control [1]

Jim Murphy
Analyst
Dynamics Research Corporation

Themes

Military operations are examined from many perspectives, and few are as challenging to capture adequately as decision-making. This effort may fall short as well, but it will not be for lack of having a conceptual framework within which to present basic issue—the absence of detailed tactics, techniques, and procedures (TTP) to support decision-making during the execution phase of operations. To make the case for the publication of detailed, generic TTPs for command post operations to be developed at the Service level, it is necessary to describe the decision-making process the TTPs are intended to support. Important supporting themes along the way include:

Doctrine – to include tactics, techniques, and procedures
Command Posts and Operations Centers
Tactical Information
Commander-Staff Teamwork
Technical, Tactical, and Digital Proficiencies

Decision-making revolves around a flow of information that commences with a requirement to conduct military operations. At the brigade, regimental, and battalion levels, the requirement from higher headquarters (HHQ) to conduct operations <u>initiates</u> the . . .

1 Orders from HHQ that include the HHQ commander's intent, concept of operations, and the tasks assigned to the subordinate and supporting units, which generates . . .
2 The unit's own restated mission, commander's intent, concept of operations, tasks to subordinate and supporting units, an operations order, and . . .
3 Once the unit begins to execute the order, a torrent of situational information.

Situational information now becomes the grist of decision-making related to the current operations order and to the successive orders. The challenge, even in the brave new Network Centric world, is how to get the right information to the decision-maker in sufficient time for him or her to make effective decisions. This challenge is described in five sections: (1) the Doctrine Gap, (2) the Current Situation, (3) Decision Models, (4) Tactical Information, and (5) A Strawman TTP Development Process.

1 ~ The Doctrine & TTP Gap

In a sense, decision-making is relatively simpler at the team, squad, platoon, and company levels that at echelons commanded by colonels and generals. The small unit leader is able to monitor and assess the situation almost entirely through his own senses. He sees, hears, smells, feels, and even tastes the information upon which he will decide to press on with his current plan or modify it. Even in sensory contact with his surroundings, uncertainty is frequently present, and the decision is reached applying a "sixth" sense, intuition. Important to note, lacking a staff, the unit leader builds his plan using the Troop Leading Procedures. In effect, he uses a doctrinal process to develop his scheme of maneuver and fire support plan. During execution, he uses doctrinal techniques, rehearsed many times, to take advantage of fleeting opportunities or to react to problems, e.g., calls for fires, hand and arm signals to change formation, immediate action drills, etc. Thus, he is equipped by doctrine to plan his five-paragraph order, and to lead the unit during execution, making adjustments to his plan as necessary.

For lieutenant colonels and above, and their staffs, sensing the battle is more complex.[2] Getting an accurate picture of the battle now requires surrogates and abstractions to supplant the "senses." This is true whether the CP is equipped simply with acetate covered maps, FM tactical radios, and 3M "stickies" or with the increasingly sophisticated C4ISR technologies. Now the commanders have help. They have a staff and equipment whose propose is to provide the relevant information necessary for decision-making, in effect, to be the surrogate for his own senses. Like the small unit leaders, the lieutenant colonels and above develop their plans and orders within a robust doctrinal framework. But unlike the small unit leaders, the lieutenant colonels and above do not have a robust, integrated doctrinal framework within which they acquire information and make decisions during the execution of their plans. More to the point, their staff members do not have a framework—either conceptual or detailed—to focus their collective efforts on providing timely relevant information to the decision-maker. They have pieces of a framework, some at a Service doctrinal level, some at a schools level, and some at a unit SOP level. But they have nothing that quite equates to small unit immediate action drills where every man in the team knows his role and the roles of the rest of the men in the element.

In retrospect, the absence of integrated conceptual and detailed doctrine (to include TTP) on decision-making during the execution phase is surprising, really. Both the Army and the Marine Corps have gone to impressive lengths to analyze, understand, codify, promulgate, and train to their doctrines for <u>decision-making</u> during the <u>planning phase</u> of an operation. But not decision-making during execution. For years, the efforts of commanders and staffs to become proficient in decision-making during the execution phase have advanced largely on the strength of oral tradition and tribal lore. With the exception of unit level standing operating procedures (SOP) for command post operations (see discussion below), which have always been prepared by the unit, individuals have had few other materials to study in preparation for command post exercises (CPX) or field training exercises (FTX). Thus, when the unit finally begins the CPX, or FTX, or even the command and control experiment, individual proficiencies pick up where they left off at the end of the last exercise and collective proficiencies start at the level of the least proficient individual—and the cycle of the old brave teaching the young brave commences again.[3] Not only is this inefficient, the ability to train to consistent standards is simply not possible. The braves carry the tasks, the conditions, and the standards around in their heads. They aren't written down, not even on the teepee walls.

Not only is the absence of integrated, conceptual and detailed doctrine for decision-making during the execution phase not good for training and readiness, it is not good for material development either. Why? Because the user cannot clearly articulate his requirement, at least not on the basis of a documented process that the material is expected to support, speed up, or possibly even supplant. The person representing the user community can only guess based on his experience what functions the material should provide.[4]

Thus two good reasons can be identified to develop conceptual and detailed doctrine for decision-making during the execution phase. First, the doctrine is necessary for unit readiness and individual and collective proficiency. Second, it provides a doctrinal framework within which to articulate material requirements for decision support systems.

As background, an interesting paradox is at work. Each system proposed is designed to facilitate decision-making at a battlefield functional level. For example, the Advanced Field Artillery Tactical Data System (AFATDS)—a system common to the Army and the Marine Corps—is designed to facilitate supporting arms decision-making and fire support coordination. It is a superb system, and is designed such that in the right circumstances, it could almost be set on "automatic pilot." It still has some developmental bugs to be worked out, particularly in the effort to integrate it fully into the Army Battle Command System (ABCS), but as a stand-alone system, it is very, very capable. The hardware system is also supported by an excellent system users manual (SUMs). While most SUMs tend to be written at the operator level, the AFATDS SUM is written so the roles of the section NCO and officers vis-à-vis the system are clear. But appropriately, the SUM does not describe the integration of the system's capabilities into the overall sequence of actions in a maneuver unit or MAGTF command post. Another document is necessary for this purpose.

The paradox then, is that even when the stand-alone system is well designed for the battlefield functional area it supports, the documentation to fully integrate the system—from the operator, the NCO, and the section officer level—into the command post process for decision-making during current operations must be accomplished by someone other than the material developer. Not all systems come from the developer with the roles of the NCOs and section officers as well defined as the role of the operator. But each system is a MAJOR element within a command post's information flow, and the NCO and section officer are integral to that process. A related reality is that the Service cannot build up from the inputs and outputs of the system to the commander's need for information. The Service must to build down from its conceptual framework for decision-making to determine what the section officer, NCO, and operator in the fire support coordination center (FSCC) must be doing to support that information flow, in addition to attending to the purely stovepipe functions of the AFATDS system.

Models and TTPS

In effect, the Services must decide on the conceptual framework for current operations decision-making, then build the TTPs/SOPs to provide timely, relevant information to the commander while concurrently continuing to enter information into the systems and appropriately acting upon the information produced by the systems. More pointedly, what is needed is (1) a cognitive model of decision-making at the colonel level that encompasses expectations, information flow, assessment, and the actual decision, (2) a team process model describing the commander–staff <u>team</u> interactions throughout the execution phase, (3) clear definition of the commander's and staff's information requirements, and (4) detailed TTP describing the collective tasks within and among the staff sections, and the individual tasks of each person with a role in the information flow.

2 ~ The Situation

Historically, command post SOPs have been the unit commander's responsibility and prerogative. The Services have developed basic doctrine for CPs—describing the organization, manning, principal duties staff members, general operations of the CP (displacement, watch standing, security, etc.), and material and equipment—but not unit level command post procedures. Currently, the Army is preparing a draft field manual, FM 6-0.6, *TTP for CP Operations*. The draft updates earlier references on CP matters and generally describes the "theory and nature" of CPs, but it will not include procedural details for the planning, preparation and execution cycle. The Marine Corps' Doctrine Division currently has in the field for review the Coordinating Draft of Marine Corps Warfighting Publication 6-2, MAGTF *Command and Control*. The draft is similar to the Army publication, and includes chapters on Information Management and Command and Control Warfare. The Doctrine Division also has plans for a MCWP 6-21, *Tactics, Techniques and Procedures for Command Echelons*. The current outline indicates that this document is also intended to be general in nature, and not prescriptive with respect to internal techniques and procedures.[5]

At the organizational level, based on a small sample of SOPs from units in the 4th Infantry Division, unit SOPS have not changed very much in twenty years. They tend to have one chapter outlining basic procedures within the unit command post. Another chapter may describe the unit's adaptation of the Army's military decision-making process (MDMP), but not the complexities of decision-making during the execution phase of an operation. As seen in Table 1,

Brigade Combat Team	Battalion Task Force	DS Artillery Battalion
Chapter 1 - Force Protection Chapter 2 - Command, Control And Communications Chapter 3 - Maneuver Chapter 5 - Fire Support Coordination Chapter 4- Intelligence And Electronic Warfare Chapter 6 - Mobility/Countermobility/Survivability Chapter 7 - Nbc Operations Chapter 8 - Air Defense Chapter 9 - Logistics Chapter 10 - Personnel Service Support Chapter 11 - Intelligence Reports Chapter 12 - Operations Reports Chapter 13 - Logistics Reports Chapter 14 - Personnel Reports Chapter 15 – Religious Support Operations Chapter 16 – Medical Operations	Preface: Commander's Combat Rules A: Command and Control B: Maneuver C: Intelligence and Security D: Combat Service Support E: Engineer Operations F: Fire Support Operations G: Air Defense Operations H: NBC Operations I: Checklists / Load Plans J: Reports	CONTENTS INDEX CARD 100 Fire Support Planning and Coordination CARD 200 Coordination of Tactical Operations CARD 300 Firing Battery CARD 400 Survey CARD 500 Combat Service Support Operations CARD 600 Communications CARD 700 Digital Troubleshooting CARD 800 NBC CARD 900 Intelligence CARD 1000 Risk Management CARD 1100 Secondary Checks CARD 1200 FDC Checks CARD 1300 Firing Incident Checklists CARD 1400 Checklists CARD 1500 Report Formats

Table 1 Chapter Headings from Unit Tactical SOPs

a list of chapter headings extracted from three unit tactical SOPs, the remaining chapters tend to have checklists related to specific tactical operations that are common to two or more subordinate or supporting units within the command.

This is not to suggest that unit tactical SOPs are not important. SOPs of this nature are useful and necessary documents, and reduce the amount of coordinating and special instructions that have to be written into operations orders. The point is that unit SOPs are not the type of written techniques and procedures envisioned in the Models and TTP paragraph above, but currently, at least in the Army (and based on this very small sample), they are the state-of-the-art with respect to decision-making within tactical command posts.[6]

One other special class of publications directly related to decision-making during operations is important to the discussion. These are the reference publications published by commands responsible for professional military education or other commands with a direct interest in doctrine and training. The texts are similar to the unit SOPs in that they highlight key tactical knowledge distilled from the Services' field manuals and warfighting publications. They also gather under one cover the Services' weapons capabilities and equipment performance information, in effect, the "know how" an officer and NCO needs in order to be, in the words of the 2d Leadership Principle, ". . . technically and tactically proficient."

In the interest of brevity, this group is listed in Table 2 along with the proponent and the URL where the reader can locate them. The bottom three documents listed are evidence of the transition in C2 support tools from maps and FM radios to the digital C2 systems now being fielded and in various stages of experimentation and development.

Source	Title	URL, etc.
Battle Command Battle Lab -Leavenworth Command and General Staff College	Battle Command Handbook Student Text 100-3, *Battle Book*	Http://cacfs.army.mil Handbook Http://www-cgsc.army.mil Organizations Center for Army Tactics ST 100-3 Online
MAGTF Staff Training Program	Pamphlet 5-0.3, *MAGTF Planner's Reference Manual* Pamphlet 6-5, *The Planner's Guide to C2PC*	Http://www.usmc.mil Units By location Virginia – Marine Air Ground Task Force Staff Training Program Center Publications – Pamphlets
TRADOC System Manager, FORCE XXI	Digital Operating Guide for Brigade and Batta lion Staffs, ABCS, v 6.1	Not available via Http.
Warrior – T	Army Battle Command System (ABCS) Version 6.2 Smart Book	Http://www.atsc.army.mil WarMod XXI Warrior-T [Call "Contacts" for passwords]

Table 2 Reference Publications Bearing on Decision-Making

In fact, none of these documents address decision-making during the execution phase of an operation, either, but they are important sources of information for a battle staff.[7,8] The information needs to be accounted for in some way in the Optimum TTP.[9]

Finally, a word on the Services' doctrinal publications bearing most directly on decision-making during current operations. On the Army side, the Combined Arms Doctrine Directorate at the U.S. Army Command and General Staff College currently has in final draft FM 6-0, *Command and Control*. As stated in the preface, the manual provides common, authoritative understanding of the authority, fundamentals concepts, and application of command and control of Army operations. It describes the art of command and the science of control. It introduces Mission Command as the preferred philosophy of command, defines control within command and control, and describes decision-making during execution (emphasis added). The manual is written both at a conceptual and detailed level, with the details still relatively conceptual in tone. It is an excellent document. It promises to fill a long standing gap, and it would be a key reference in developing the Optimum TTP.

The Marine Corps Doctrinal Publication series addresses decision-making entirely at a conceptual level. MCDP 1, *Warfighting* sets the broad architecture; MCDP 6, *Command and Control*, defines it further; and MCDP 1-3, *Tactics* refines elements in MCDP 6. The Coordinating Draft of MCWP 6-2, *MAGTF Command and Control*, provides additional organizational detail.

Thus far the discussion has attempted to make the case that TTP should flow from concepts, preferably doctrinal concepts. The Army is on the verge of publishing relatively detailed doctrine on decision-making during execution. The Marine Corps, as depicted on the Doctrine Division's doctrinal hierarchy diagrams, has no plans to provide Service level doctrine beyond the conceptual documents already in the field. The tentative conclusion is that neither Service will publish doctrinal publications in the near term that will provide sufficient detail to frame the TTP.

3 ~ Decision Models

Earlier the discussion stated that what is needed is (1) a cognitive model of decision-making, (2) a team process model, (3) clear definition of information requirements, and (4) detailed TTP describing the collective tasks within and among the staff sections. In effect, while the objective is to develop TTP, logic requires starting with the actual cognitive decision-making process.

A Cognitive Model

The decision-making process for planning and execution decisions is highly cognitive. The process has been described extensively in the literature of psychology and increasingly in military periodicals and papers written by officer students during their attendance in professional military education. Indeed, the Marine Corps *Gazette* has featured articles by Dr. Gary Klein, one of the foremost cognitive psychologists in the United States. Dr. Klein has written extensively on the subject of "recognition-primed decisions" and the function of expertise and intuition in decision-making. Prior to his research and espousal of recognition-primed decisions, military officers were trained to believe that all decisions, to include decisions during execution, had to be preceded by the development of two or more courses of action (COA) and a trade-off analysis to identify the best alternative. Never mind the reality that commanders in time constrained circumstances tended to size-up the situation and personally prescribe the single COA they intended to execute. Clearly, Dr. Klein's research, writings, and many presentations broke the multiple COA logjam, and have significantly influenced every other military and academic writer addressing the topic. That said, the recognition-primed decision (RPD) model is not sufficient by itself to describe the full range of factors influencing a commander's decision during current operations.

In 1998, an Army Research Laboratory effort attempted to expand on the RPD model to account for other factors known to influence a commander's decision. These factors are implicit or referred to in the RPD descriptions but are not the point of emphasis. The factors are sufficiently important that they needed to be highlighted in a more comprehensive model of military decision-making. The ARL project director believed that a cognitive model of a military decision had to account more fully for three other factors:

1. That the decision-maker's frame of reference for the decision was significantly influenced by his military training, education, experience, together with the mental images created by the HHQ order and the unit's detailed plans bearing on the current situation,
2. That the cognitive function of situation monitoring needed to be expanded. This concerned specifically the periods when either the plan was fully on track or "nothing was happening," and then cues or triggers caused the decision-maker to begin to assess the changing situation, and make a decision. And finally,
3. That many military decisions are made under conditions of uncertainty, not recognition, and that cognitive decision strategies under these conditions needed to be explained in more detail.

The team combined a detailed literature review with field observations at a series of Army advanced warfighting experiments (AWE). The intention was to fit the models to the actual decision-making processes observed in the field, not fit the observations to the models. Figure 3 lists the principal concepts, researchers, and articles representing the researchers' views that became the nucleus of the integrated cognitive model:

Researcher(s)	Article (See bibliography)	Emphasis in the Integrated Model
Beach	Image Theory: Personal and Organizational Decisions	The function of military training, education, experience in decision-making, together with the mental images created by the HHQ order and the unit's detailed plans bearing on the current situation
Rouse and Valusek	Evolutionary Design of Systems to Support Decision Making	Situation monitoring and the onset of situation assessment
Klein	A Recognition-Primed Decision (RPD) Model for Rapid Decision Making	Recognition-primed decisions
Lipshitz and Strauss	Coping with Uncertainty: A Naturalistic Decision-making Analysis	Coping with uncertainty; cognitive strategies to with which to make effective decisions under conditions of uncertainty.

Table 3 Cognitive Decision Models Bearing on Military Decision Making

The resulting model is portrayed in Figure 1, Integrated Cognitive Model of the Commander's Decision Process (Adelman, et al., 1998).[10]

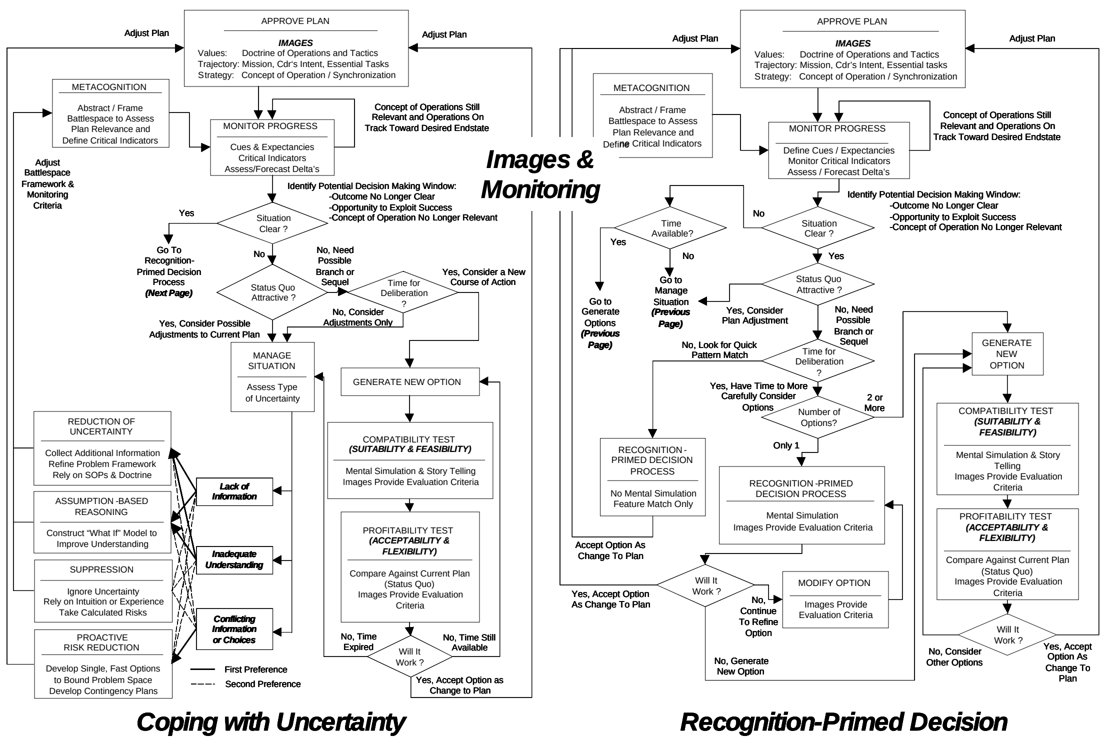


Figure 1, Integrated Cognitive Model of the Commander's Decision Process

The purpose here is not to describe the development and logic flow of the model; rather it is to provide an example of a cognitive model specifically developed to describe a military commander's decision-making process during the execution phase of an operation. As a footnote to this model, the lead author for the Draft FM 6-0, *Command and Control*, said that the model—the graphic and the detailed discussion—contributed significantly to the decision process model described in that publication.

A Commander-Staff Team Process Model

The research effort that produced the cognitive model also produced the beginning of a commander-staff team process model. This model has grown over the past three years from one diagram and a list to four diagrams and a different list. It starts with a description of what the commander and staff actually monitor (mostly).

Tactical Deltas

The ARL effort produced insights not only into the cognitive process, but also into the factors that most frequently caused a ground maneuver commander to consider making a decision. As this analyst examined decision after decision, the most common elements to all of them was that the decision involved (1) a subordinate or supporting unit, or an enemy unit, or a piece of terrain—no surprise—and (2) a condition had changed with respect to the unit or terrain that was not consistent with the plan as currently set. In effect, as the situation monitoring continued in the command post, the commander or a staff member noticed that one or more units' situations had changed in a way that was not as projected in the plan, and the change had the potential to create an opportunity or cause a serious problem.[11] The differences between the plan and the current situation were termed "tactical deltas." Tactical deltas indicated an opportunity had presented itself, or that a unit would not be able to accomplish an assigned task The implications of the delta normally lead to a decision. The decision would always result in either changing one or more units' task(s) (and normally the purpose), or changing the direct support provided to one or more units, or changing a graphical control measure to provide a spatial advantage to a key unit. Small deltas between the plan and the situation that did not impair the mission normally did not cause the commander to make a decision (although, a decision to make no change is still a decision).

The changes in situations that would generate active assessment always reflected back on some element of the unit's mission. Situations varied in gravity from a unit not being able to accomplish a minor task to situations so serious as to put the HHQ commander's end state at risk. So, very simply, the commander and staff monitored the situation focusing on the units and the key terrain. They were alert specifically for changes in a unit's situation that affected its ability to accomplish assigned tasks. When they detected a delta, they assessed the situation in the context its implications for their accomplishment of their mission, and in very serious cases, its implications for their HHQ commander's mission and intentions.[12] Figure 2 is a graphic of the major elements in the monitoring and assessment of tactical deltas.

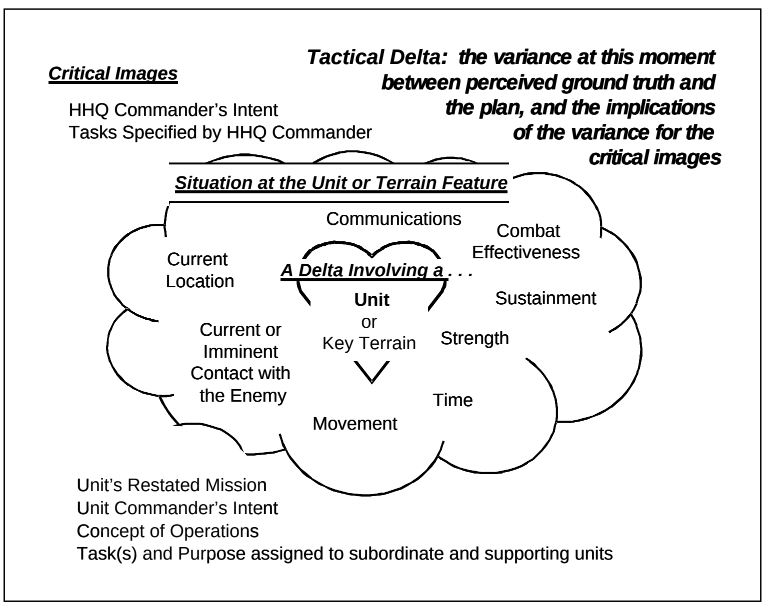


Figure 2 Tactical Deltas

Cognitively speaking, once a delta is detected, the commander or a staff member assesses it to determine the implications with respect to the critical images. The commander can make a decision entirely without input, and in time sensitive cases that was observed to happen. But it is also true that give time for discussion, the commanders also sought input from their staffs.

Picture "A Decision"

Once the commander staff interaction begins with respect to a given delta, a simple process unfolds, although some of the deliberations can be very complex depending upon the situation. Figure 3 is a diagram of the commander-staff process as the commander decides what to do relative to a emerging tactical delta.

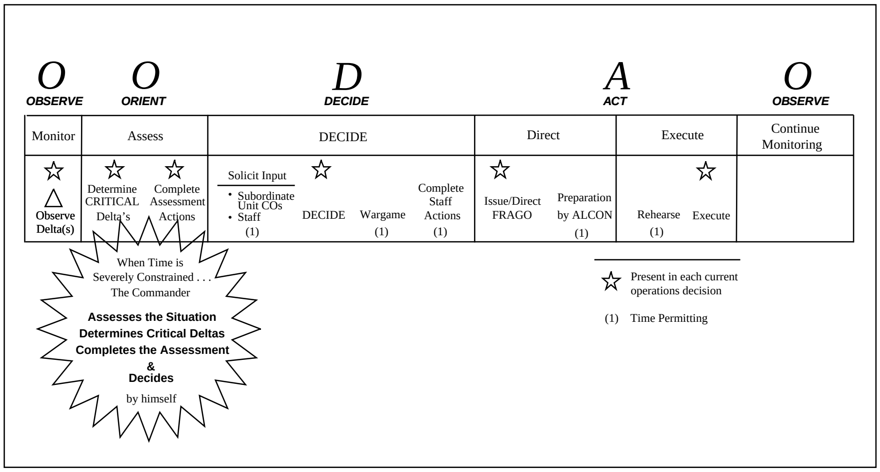


Figure 3 A Single Decision During Current Operations

It is a rare operation when the unit accomplishes its mission and achieves the HHQ commander's end state with only a single decision having been made during the execution phase. A more interesting picture emerges when a series of notional decisions are arrayed in terms of the specifics of an operations order.

Picture the Decision in Terms of the Plan

Figure 4 represents graphically the decisions reached during the planning process. It shows the conceptual and tasking components of the operation order (OPORD) that the unit is attempting to execute. In the conceptual portion of the order, the commander has expressed his intent and his concept of operations. In the tasking part, he assigns tasks (with purpose) to his subordinate and supporting units. The battle staff must understand the purpose of each subordinate unit task as well as the subordinate unit commanders understand them. In almost every situation, a tactical delta(s) arises while a unit is attempting to accomplish an assigned task. Thus the assessment must clearly include the implications of the situation with respect to the purpose for which the task was assigned. If one purpose is in jeopardy, other elements of the plan are in jeopardy. In Figure 4, the time is just prior to H-hour. The unit has completed its rehearsal and is poised to attack.

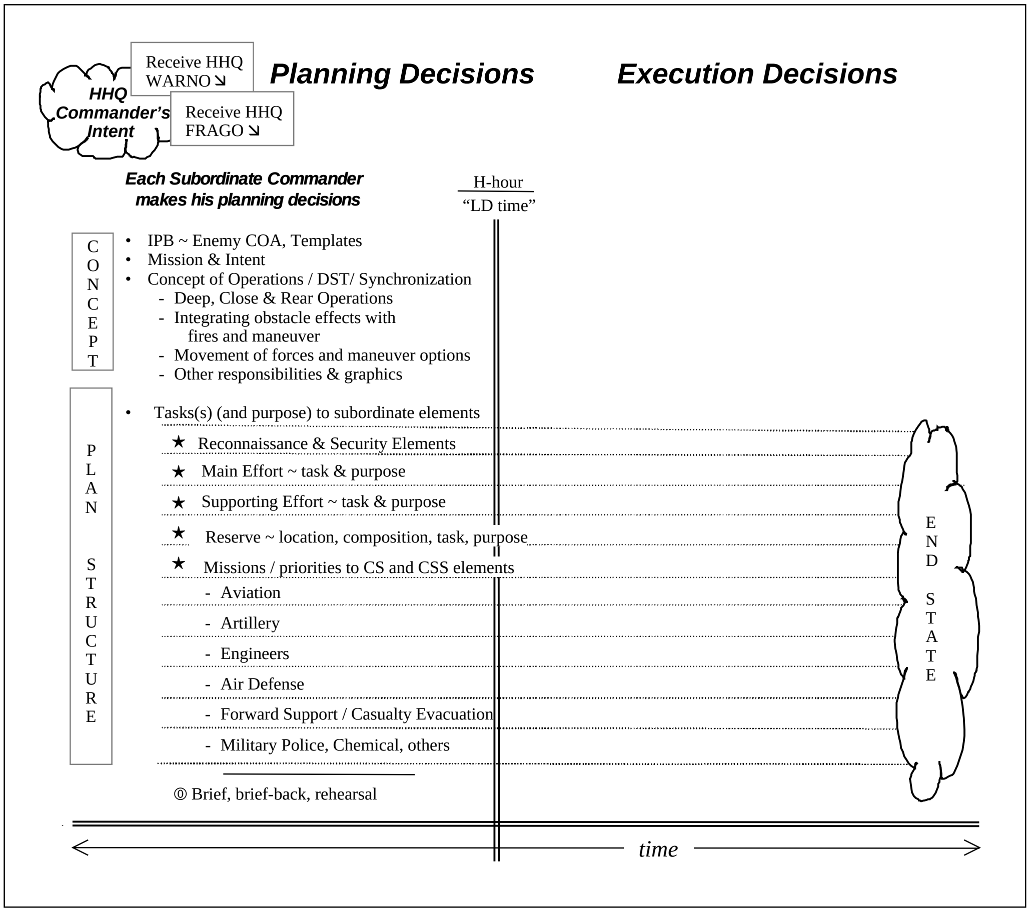


Figure 4 Planning Decisions and the Operations Order

Now complete the graphic by crossing the line of departure, executing the assigned tasks, and achieving the commander's end state. Figure 5 is a notional view of a series of decisions made during the execution phase. The small bars on the right side of the graphic represent decisions arrived at through the commander-staff group process in Figure 3. Once the command crosses the line of departure, the plan becomes fluid. The thinking adversary is also flexing his will. Variances—tactical deltas—are beginning to be received in the command post.

During the execution phase, the battle staff monitors and assesses each variance, paying particular attention to the implications of the information with respect to the overall plan. The information is assessed for the degree to which it has the potential to affect, or is already affecting the concept of operations. Exactly what action(s), if any, are decided is a function of the situation and the expertise of the officers participating in the assessment. Their role is to understand whether the implications of the information are positive, neutral, or adverse to friendly actions currently underway, or planned, and to know what options to outline and recommend to the commander. Through discussion with the staff, the commander reaches a decision. Once the decision is made, and the fragmentary order is issued, the situation monitoring continues.

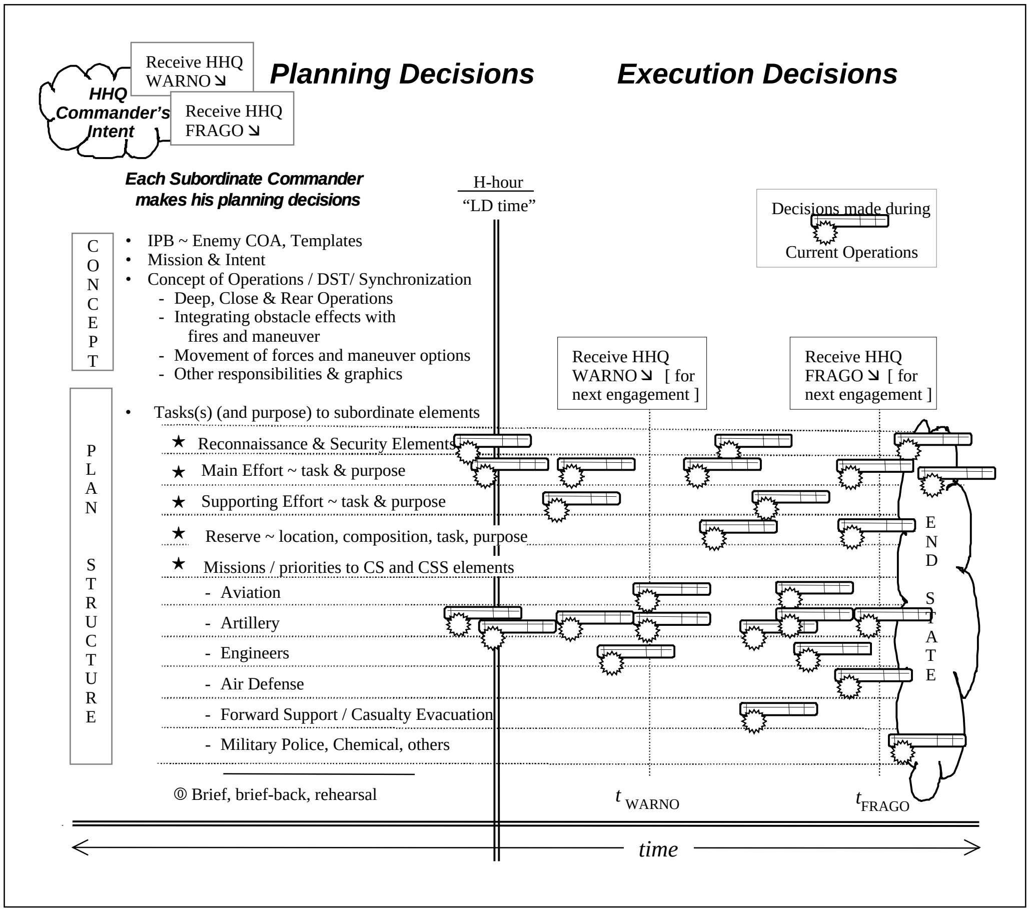


Figure 5 Decisions Made During Current Operations

The initial series of tactical tasks in an operations order are normally reasonably well synchronized. Once the operation starts, the tactical information flowing into the command post can cover each battlefield functional area and every facet of the commander's OPORD—and therefore, each piece of tactical information that passes the data filters bears on the overall synchronization. The commander and staff attempt to understand what each piece of information means in terms of the synchronization. They will determine what must be done with respect to the particular information, how that action affects the overall synchronization, and what must be done to maintain the synchronization that still applies. As the operation continues, the well-choreographed synchronization begins to be overcome by cascading events, and the staff continues to synchronize the following actions literally "on the fly."

The hard part is timing the movement and relocation of committed assets—the reserve, artillery batteries, ADA units, engineer platoons, forward support units, tactical bridging, etc.—to ensure they are in position to continue to support the main and supporting efforts, as necessary. This timing frequently needs to be worked out with all interested parties listening to the discussion. Teamwork and "know how" are critical. Circumstances will determine whether the discussion should take place at the situation map (digital or analog), or off-line.

In effect, the current pieces of tactical information are being assessed for implications of the actions associated with that information—and if the actions were left to continue, how they would affect the current plan. Clearly, and at frequent intervals, two or more elements of information have to be considered a whole. But whether the commander deals with single elements of tactical information or clusters of information considered as a complex whole, he tends to make his decisions serially.

These activities do not bring to mind the recognition of a series of patterns setting in motion a grand response. They bring to mind a multifunctional group of competent, proficient persons performing fast-paced, serial problem solving to keep a fluid enterprise on track toward a goal—a goal, which, in the beginning, had been determined to be feasible and acceptable.

4 ~ Tactical Information

More granularity accrues to the decision models by considering the decision support environment in the command posts, particularly number of persons involved in the information flow. This section looks briefly at one command post simply to appreciate the numbers of people and systems in it. The section also considers the commanders information requirements.

"A" Command Post

Consider the environment in which many decisions are made, the command post. The reason is to highlight the number of persons with active roles in supporting the decision process, and to have a sense of the physical environment in which information flows and decisions are made.[13] Figure 6, on the following page, is a sketch of an Army light infantry tactical operations center (TOC) in a recent advanced warfighting experiment focused on the Army Battle Command System (ABCS).[14] The figure shows 34 + persons in the TOC, a surprising number, but perhaps not, considering the number of functional activities the battle staff performs in the space. The purpose is not to enumerate the activities, they can be discerned by examining the sketch, nor is it to highlight features of the layout. The purpose is to spark the reader's imagination—given the number of soldiers and C4ISR systems—of the torrent of information this colony is capable of producing, particularly considering the ABCS systems in the sketch are only one node in a wide area network of many nodes. Yet, parenthetically, having observed five of these operations centers over several weeks, the analyst has yet to observe an occasion when the commander and key staff members have been in a condition of "information overload." This is not to say the potential does not exist, it simply has not occurred to date. The units have not won all their engagements, but the shortcomings on these occasions were having too little information, particularly top down intelligence, not having an overload of information. In fact, the shortfalls were people not knowing how to process information that was present or was reasonably available from other nodes.[15] The absence of adequate TTPs contributed to their lack of proficiency.

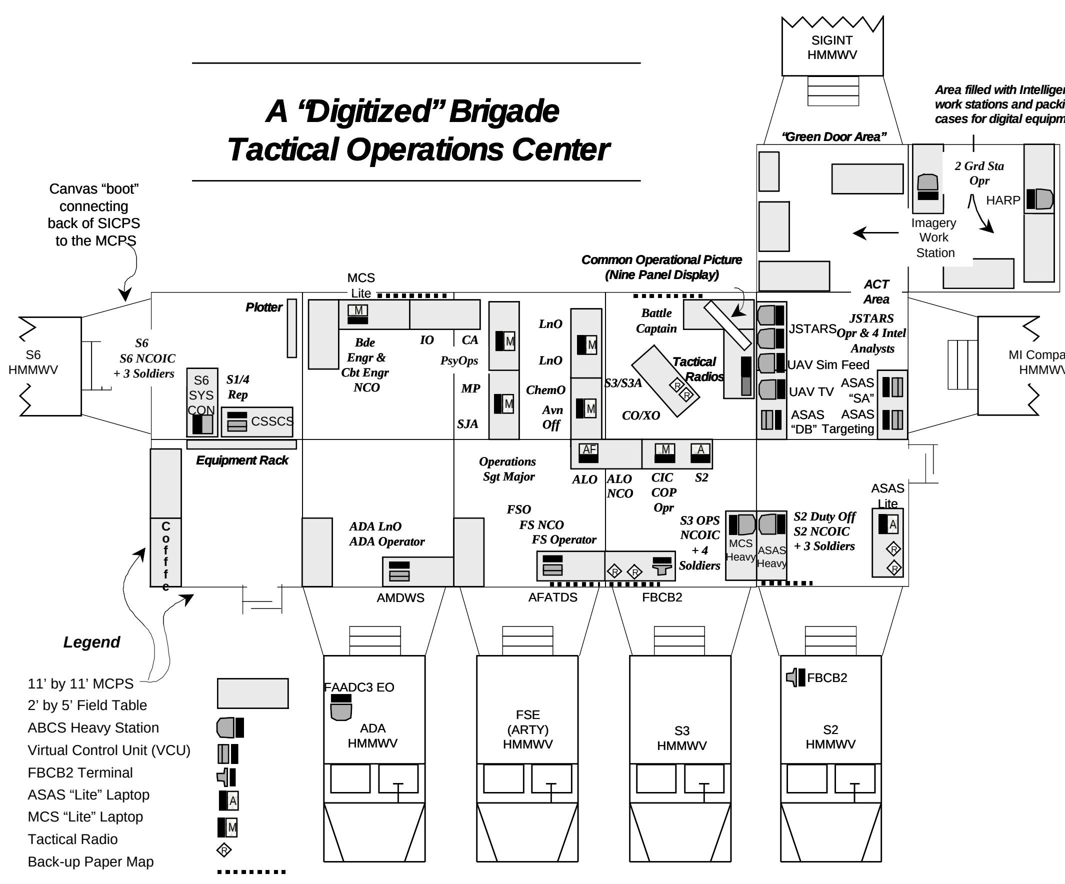


Figure 6   A Digitized Army Brigade Tactical Operations Center

The command post exists to enable the commander to command and control his units in accomplishing their assigned mission. During the execution of each mission, uncontrollable external circumstances almost always arise, necessitating a series of decisions adjusting the plan. The oxygen that enables these decisions is information. It is useful to ask again, what information? Within the CP, where does it come from? Who provides it? How is irrelevant information screened out? Who does that screening? This set of questions has implications for command post TTPs/SOPs.

Information Requirements

Generally, a discussion of information requirements centers on whether or not the Commander's Critical Information Requirements (CCIR) include everything a battalion, regimental, or brigade commander needs to know and to be apprised of by the battle staff.[16] The answer is that it depends on a person's viewpoint. After a recently concluded AWE, and concerned that discussions of information overload never advance to addressing specifics, this analyst attempted to list the specific information that a commander needs during the execution phase. The idea was that if people cannot clearly describe the specifics of information overload, perhaps it is possible to forestall information overload by stating clear criteria for the information that should be actively processed. Given a list, such as the one below, if the flow of information were still overwhelming, then pare down this list. The list in Table 4 was purely a heuristic exercise; another analyst would compile a different list. The larger point is that if a doctrine developer can identify the information categories to a reasonable degree, this facilitates identifying each battle staff member's responsibilities to the commander for required tactical information.

1	Higher Headquarters orders as soon as they arrive (warning orders, fragmentary orders, operations orders)
2	Current and predicted enemy situation in the unit's areas of interest (AI) and area of operations (AO)
3	Critical incidents involving ROE, Fratricide, civilians or public affairs in the AO, and political-military interests appropriate to the echelon of command
4	Information received answering the higher headquarters commander's CCIR
5	Information received answering the commander's o wn CCIR
6	Information related to Decision Points
7	Status of subordinate, supporting, and adjacent units relative to their progress in accomplishing assigned tasks and purpose. Within this category, the commander needs to know the progress o r problems encountered in executing the Reconnaissance and Surveillance Plan; and again, the progress of each subordinate and supporting unit in the context of the discussion of "tactical deltas."
8	Changes in status of data and voice communications
9	Changes in status or the projected status of logistics by key classes of supply and personnel specifically as each affect the capability of the unit to accomplish the current mission and operations now in the process of being planned. Some of this will be duplicative of the FFIR in the CCIR (see definitions below).
10	Immediate appraisal of the emergence of other unexpected or unforeseen events, which affect the higher headquarters commander's intent or the commander's own intent, or are problems of such magnitude that only the commander can address them.

Table 4 The Commander's Information Requirements During the Execution Phase

It is also important to remember that once operations commence in a contingency area, the planning phase of the next operation runs concurrently with the execution of the current operation. For instance, the commander is now forward at a tactical CP in the midst of the current operation. Receiving the HHQ warning order for the next phase of the major operation or campaign, he calls the nucleus of his operational planning team (OPT) forward to be briefed on the IPB related to the mission, and the OPT's initial mission analysis of the order. Given this information, he then provides them guidance on the COA development and analysis, giving the OPT the information they need to continue planning. In this case, necessarily, the commander is dealing with information from different phases in two sequential operational cycles.

The discussions of the command posts and the information requirements are intended to highlight the necessity for command post TTPs to link individuals within the CPs to the information they routinely work. The CP environment has always been more complex than the "tried and unused" CP SOPs managed to covey. Perhaps the environment was so complex that attempting to work through the details was "too hard," and it was easier of salute the idea that the procedures within a command post were the prerogative of the commander. With the advent of the digitized C2 systems, the environment is even more complex. As mentioned earlier, it is interesting that both the Army and the Marine Corps have published very detailed doctrine for decision-making during the planning phase, but have expended little effort on execution decisions. Planning decisions have always been considered to be more analytical than execution decisions. The people that describe them as exercises in Newtonian logic have a point. At the same time, although more complicated, execution decisions are far more fathomable than to say they are essentially a "blow of the eye," the application of "intuition" to "situational awareness." The "models" discussion (and the studies upon which it is based) suggests that current operations decisions at the battalion, regiment and brigade (not at the company and below) are as analytical as planning decisions, but they are generally made in time-compressed circumstances, on the basis of one course of action, and frequently the commander does so under conditions of considerable uncertainty. And, yes, the commander's tactical judgment, resulting from training, education, experience, and intuition, is very important. But the judgment needs to be fed timely, relevant information. Focused TTPs, developed on the basis of sound concepts and models, can leverage the judgment.

5 ~ A Strawman TTP Development Process

The doctrine developer cannot leap from the models to writing the TTP without several intermediate steps. Unless the developer appreciates the "team" nature of the activity, the TTPs are likely to resemble the individual task lists in the current SOPs. While a task analysis will be necessary later in the process, the first tier analysis is to reach a consensus on the nature of the decision making process during the execution phase. The models presented earlier are not the final answer to the model question, simply a useful start point. The second tier analysis is to identify the commander-battle staff team proficiencies necessary at the aggregate level. Driving this approach is the increasing presence of digitization and the need to ensure its capabilities are factored into the TTP starting from the top down, not from the operator up. The third tier analysis, closely related to the second, is to split out the proficiencies necessary within the functional teams (operations, fires support, intelligence, etc.). The fourth tier is the individual tasks, but it includes the "know how" a battle staff member should have in his or her active memory or cargo pocket.

2d Tier ~ Commander-Battle Staff Team Proficiencies: teamwork more productive than task work

Among the more interesting of the Army's research initiatives related to digitization and the teamwork necessary within command posts is an effort to develop a "multilevel systems model of the Army Battle Command process," and specifically, the team processes necessary to increase proficiency amid the increase in information systems (IS) and information technology (IT). The idea is simply that at the center of a C4ISR system lays a distributed human decision-making process—a process that can be supported by technology; but, a process that is still governed by human interactions. How people, teams, and human organizations use and adapt to new information systems and information technology, new procedures, new organizational structures, and new environmental complexities remains at the heart of the performance issue. Previous research on decision-making under high time stress conditions suggests that the greatest increase in battle staff proficiency will occur in the area of *teamwork*, not individual task work.

Behaviorally Anchored Rating Scales

The idea has been to identify from a behavioral science perspective, the team proficiencies needed to exercise effective command and control, then develop sets of assessment scales for each team proficiency area identified. The technique used is a training adaptation of a personnel performance appraisal methodology called *behaviorally anchored rating scales (BARS)*. The technique has been used to develop training support packages for Army and Air Force aircrews in cockpit resource management and for hospital emergency room staffs. Teamwork in cockpits and emergency rooms is characterized by the need for information and time-critical decisions. In fact, ARL has completed a pilot effort to identify commander-battle staff team proficiencies.

The project focused on developing commander-staff proficiency rating scales to be used by observer controllers, and is not focused on command post TTP, *per se*. The project reached its objectives, and while the BARS that have been produced are short of the detail needed for TTP, the products indicate what could be accomplished with a very rigorous application of the classic BARS development method.

A "Reverse Engineered" Prototype

Because the project was a prototype, Dr. Dennis Leedom, the director and a very experience cognitive psychologist with 30 + years experience in military training analysis and cognitive research activities, developed an initial set of 17 "battle command" proficiencies (Leedom, 1999). He built the list based on his extensive knowledge of the literature pertaining to the subject, and, of course, his considerable experience. In classic BARS development, the 17 proficiencies would have been developed entirely on the basis of input from military practitioners. The military persons are absolutely critical to the process because they are the subject matter experts (SME); the psychologists in the classic BARS development process are facilitators and scale development experts only. The military SMEs and the psychologists together develop the behavioral scales. In this case, military SMEs were not available, and since the project was a prototype, the project commenced with an educated "best guess" set of performance dimensions.

With that as background, it is interesting to note that the 17 team proficiencies in Table 4, below, are written in generic, non-military language. They could apply as easily to a civilian organizational environment as a to a military unit. Dr. Leedom's paper provides behavioral descriptions of each proficiency, which make clear that the proficiencies are intended to for military applications.[17] That said, a military reader may conclude on first reading that a number of the performance dimensions, even if they were written in military language, may not be right. That's okay. The point here is only to layout a proven technique for developing the top-level team proficiencies, then developing the collective proficiencies within each staff and liaison team section.

Performance Area		Behavioral Proficiency
Establish Team–Organizational Structure & Process	1	Clarify Expected Roles and Contributions of Individuals-Teams
	2	Establish Clear Strategy for Knowledge Management
	3	Establish Effective Information Exchange Practices
	4	Establish Supportive Behaviors and Error Monitoring
	5	Align Decision Authority With Decision-Making Capacity
Manage Decision and Production Strategies	6	Employ Proper Mix of Decision Strategies for Each Situation
	7	Effectively Manage the Collaborative Debate Process
	8	Sequence and Communicate Decisions and Assumptions
	9	Employ Proper Mix of Production Strategies for Each Situation
Manage External Situation Awareness Process	10	Balance Push-Pull of Information Flow to Decision-Makers
	11	Maintain Attentional Scanning Across Multiple Decision Threads
	12	Verify Key Information Inputs and Employ Proper Risk Management
	13	Manage Battlespace Images and Their Cognitive Shaping Influence
	14	Anticipate and Prepare for the Emergence of Complexity
Monitor & Adjust Team–Organizational Process	15	Manage Task Priority, Task Sequencing, and Information Cost
	16	Manage Process Error Associated With Staff Rotation and Handover
	17	Practice Continual Self-Critique and Organizational Learning

Table 4 Prototype List of Commander-Staff Team Proficiencies

The proficiencies are actually fairly broad, and encompass several sub-proficiencies, or "team tasks." The project team's challenge was to decompose the 17 proficiencies into the sub-proficiencies, then develop three behavioral descriptions of each sub- proficiency ranging from highly effective behavior, to basically effective behavior, to ineffective behavior. Again, in classic BARS development, the process of developing the behaviors is based entirely on the input of the military SMEs. In fact, in a classical BARS development project, the first step is to develop a large number of descriptions of behaviors the military SMEs have actually seen in the field related to the entire functional area, or the job being studied. The SMEs literally write each behavior on a 3x5 card. The second step is for the SMEs to cluster the behaviors into stacks related to the major tasks that comprise the total job. These stacks are referred to as performance dimensions, although in Table 4, they are listed under "Behavioral Proficiency." For example, performance dimensions for a staff officer would include "planning skills" and "coordinating skills." Some of the described behaviors in the stack will achieve highly effective results; some will achieve only acceptable results, and some will produce unsatisfactory results. The military SMEs, not the psychologists, assess the effectiveness of each behavior in the performance dimension. The third step is to array all the behaviors in each stack in order from most effective in achieving the result, to least effective. In some BARS projects, numerical scales are assigned to the range of behaviors.[18]

The result is a set of scales for each major dimension of the overall job, and each set of scales identifies behaviors that a trainer, for instance, is likely to see when observing people performing the task.

Thus a trainer could observe the staff performing the particular activity, identify the staff's behaviors on the list of behaviors (the BARS), and subsequently be able to counsel the staff on their performance in getting the job done. The staff being counseled would normally agree that the behaviors identified by the trainer were in fact an accurate description of manner in which they were conducting themselves when observed, thus validating the observations. The next step would be improving the staff's proficiencies so they could move to the next level of effectiveness.

In fact the project team quickly confirmed that each of the basic 17 team proficiency dimensions contained easily identifiable sub-proficiencies. This is not surprising given the complexity of the entire commander–battle staff–command post environment. Table 5 shows two proficiency dimensions from Table 4, each with several sub-proficiencies.

3 - Establish Effective Information Exchange Practices	**8 - Sequence and communicate decisions and assumptions**
Use doctrinal terms and standard formats Transfer clear, timely, complete information Verify information receive and validate its implications for the on-going plan (when appropriate) Acknowledge receipt Verify acknowledgement	One third, two thirds rule and planning timelines Timely warning orders and interim planning products Use of Liaison Officers

Table 5 Examples of Proficiency Dimensions and Sub-Proficiency Dimensions

Calibrating the Effort

As the reader will sense from the following example of a prototype set of BARS, the detailed, scaled behavioral descriptions are one level of effort further than necessary to develop effective TTPs. But the basic BARS development process, particularly the involvement of the military SMEs to identify the full range of team proficiencies and sub-proficiencies, represented in small part in Table 5, is a very sound method. Supplemented with a robust literature review, and tailored to recognize the expertise of the participants, the classical BARS development approach would accelerate an effort to develop sound team level TTP. That said, the following table provides an example of the team behaviors for one sub-proficiency in Table 5.

Observational Focus One Third, Two Thirds Rule & Planning Timelines. Does the battle staff complete planning and issue the operations order within the one-third, two-thirds guideline? Does the battle staff develop an internal planning timeline very soon after receipt of mission and adhere to it? Does the battle staff subsequently coordinate timelines with it's higher headquarters, and issue an expanded planning-briefing-rehearsal timeline to it's subordinate units?
Exceeds standards (Rating 7): Battle staff performance of sequencing and communicating decisions and assumptions enhances team effectiveness (Few if any errors). The commander and staff are well-disciplined to execute their planning requirements within the 1/3 – 2/3's allocation of time. The staff first determines the amount of time in the 1/3 allocation, then determines 1/4 of the time, and allocates the 1/4 to the MDMP planning tasks. Once planning is underway, the XO or S3 coordinates with HHQ to determine the times for the brief back to HHQ and the HHQ's rehearsal. The S3, with the CO's approval, issues the unit's own briefing and rehearsal times to the subordinate units.
Meets standards (Rating 4): Battle staff performance of sequencing and communicating decisions and assumptions contributes to team effectiveness (Recoverable errors). The commander and staff normally executes their planning requirements within the 1/3 – 2/3's allocation of time. The staff first determines the amount of time in the 1/3 allocation, and further

allocates it to the planning tasks. The staff tends to wait for the higher headquarters to announce its briefing and rehearsal schedule. The S3, with the CO's approval, issues the unit's own briefing and rehearsal times to the subordinate units.
Below standards (Rating 1): Battle staff performance of sequencing and communicating decisions and assumptions jeopardizes team effectiveness (Unrecoverable errors). The battle staff invariably overruns the allocated time, taking up to 1/2 the time available. The staff simply has difficulty completing all the steps within the time intervals they initially determined. The unit tends to wait for the higher headquarters to announce the briefing and rehearsal schedule, and as a result, frequently does not begin to coordinate this schedule until they have completed their operations order. This causes other subordinate units to have to cancel key activities.

Table 6 Example of Prototype BARS for One Sub-Proficiency

The BARS developed to this level would be useful in a training situation, but are clearly more than is needed to establish the full range of team proficiencies for a comprehensive command post TTP. The object is to identify the multilevel systems model of commander-battle staff team proficiencies, and a traditional task analysis may not be the methodology for the effort. But the basic BARS development process, particularly the involvement of the military SMEs would identify the full range of team proficiency dimensions, and the third tier staff and liaison section proficiencies as well. The BARS technique can include more than one group of military SMEs, and arguably it should. The effort to identify the effective team level behaviors should be as inclusive as possible.

It is feasible for a project team comprised of military SMEs to identify TTP simply on the basis of a literature review, small group discussions, and interviews. The group would want observe several exercises, as a group, as part of the process. The output of the effort is likely to be oriented more to individual and section tasks, than to commander-staff level team proficiencies. But this approach is far preferable to no TTP at all.

Any approach to developing TTPs that will describe the flow of information within the command post to get the right information to the commander for decision-making is an acceptable approach. It is even more acceptable if it is sufficiently descriptive that persons performing duties in a command post can read the document before an exercise to improve their personal proficiency.

Summary

This short paper covered a relatively broad stretch, relying on the reader's curiosity to look a second time at the detail in the tables and figures to fill in detail I have passed over. Time and space did not permit explanations of the usefulness of the integrated cognitive model, for example, but the implications of simply understanding the range of strategies in which decision-makers tacitly deal with uncertainty are significant. Some of the coping mechanisms would not occur to a person naturally, but being aware of them adds insight and future stratagems to the reader's store of tactical judgment. The process model is useful as well. It should cause the reader ask exactly what the range of staff drills should be to deal with the most frequent of the tactical deltas across each of the battlefield functional areas. Figure 5, showing the series of decisions made during the execution phase, suggests the staff has a vital role in ensuring at the end of each fragmentary order that the remaining shards of the original order and the urgent new tasks are all synchronized toward key tasks, and still contributing to the original intent if that is still feasible. The list of commander's information requirements is a simple strawman, but it provides a framework for commanders and their staffs to continue their discussions of critical information, or start if they have not done so already.

The behaviorally anchored rating scale methodology of identifying what people and teams do is a solid technique for getting a group of military officers and NCOs talking about what need to be done in a command post. Other techniques will reach the same objective, but this is an interesting one that has been tried recently on commander-battle staff team proficiencies.

Finally, I have attempted to make the case for doctrine focused on decision-making during the execution phase. The doctrine needs to include a cognitive description of the process, a commander-battle staff team description, and it needs to reach down to the TTP for teamwork in the increasingly digitized command posts in the land warfare Services. Information technology has the potential to support the cognitive processes, or frustrate them because of bad design. Either way, the TTP are so complicated it is unreasonable to expect battalion, regimental, and brigade commanders to work them out at the unit level. Detailed, generic TTP for digitized command post operations are DOTES/DOTMPL responsibilities.

#

References

Adelman, L., D.K. Leedom, J. Murphy, & B. Killam (April, 1998). Description of Brigade C2 Decision Process. Andover, MA: Dynamics Research Corporation. (Prepared under Contract DAAL01-95-C-0115 for U.S. Army Research Laboratory, Aberdeen Proving Ground, MD.)

Beach, L.R. (1993); Image Theory: Personal and Organizational Decisions. In G. Klein, J. Orasanu, R. Calderwood, & C.E. Zsambok, Eds., *Decision Making in Action: Models and Methods*. Norwood, NJ. Ablex (pp. 148-157)

Klein, G. (1993); A Recognition-Primed Decision (RPD) Model of Rapid Decision Making. In G. Klein, J. Orasanu, R. Calderwood, & C.E. Zsambok, Eds., *Decision Making in Action: Models and Methods*. Norwood, NJ. Ablex (pp. 138-147)

Leedom, D.K. (1999); Development of a Framework for Assessing C4ISR Performance: Critical Battle Command Proficiencies. (Working Paper) 2d Draft, May 26, 1999,U.S. Army Research Laboratory, Aberdeen Proving Ground, MD

Lipshitz, R., & O.Strauss (1997); Coping with Uncertainty: A Naturalistic Decision-Making Analysis. *Organizational Behavior and Human Decision Processes*, 69(2) (pp. 149-163)

Rouse, W.B., & J. Valusek (1993); Evolutionary Design of Systems to Support Decision Making. In G. Klein, J. Orasanu, R. Calderwood, & C.E. Zsambok, Eds., *Decision Making in Action: Models and Methods*. Norwood, NJ. Ablex (pp. 270-286)

ENDNOTES

[1] Referring to Army brigades which, like Marine regiments, are normally commanded by a colonel and are comprised of three battalions.

[2] The lieutenant colonel and colonel level decision situations are the most challenging because they are the first two echelons where the commander is out of personal sensory distance of the battle, but they have the shortest windows within which to access the situation and make a decision. This means the quality of the information they receive from their own units and from Higher headquarters must be very good and very timely. The window is so short that the intelligence systems at the higher headquarters are hard pressed to provide fused, analyzed intelligence to the "colonel" commands in time for the commanders to use it effectively.

[3] In some cases in the "high tech" command posts, due to the older braves being not nearly so computer savvy as the young braves, the roles have been slight reversed. Fortunately, in increasing numbers of cases, the senior NCOs have recognized the necessity to become computer literate, and the old brave model is reasserting itself.

[4] Hypothetically, the absence of a conceptual and detailed frame work as basis for requirements could also result in requirements people identifying a less urgent requirement as the focus for development and experimentation.

[5] Of interest, the Marine Air Ground Task Force Staff Training Program (MSTP) Center's home page features a series of training materials used by the MSTP staff during their training events with Marine units and groups. A slide in the lesson materials for the "Execution" class says that (1) commanders us SOPs to standardize routine or recurring actions not needing their personal involvement, (2) SOPs include specifics on the organization, functions, and responsibilities of a particular commander's staff, (3) organization for combat that differs from day-to-day operations should be clearly defined by the command's SOP, and (4) benefits of SOPs are (a) simplified, brief combat orders, (b) enhanced understanding & teamwork among commanders and staff, (c) established synchronized staff drills, and (d) established abbreviated or accelerated decision-making techniques. (c) and (d) are interesting, but at the moment, the author has no examples of Marine Corps unit SOPs to comment on the manner in which the units have described the synchronization drills and the abbreviated decision-making techniques.

[6] With respect to Marine Corps SOPs, during the brief window in which I prepared this paper, I did not have the opportunity to request and review any Marine Corps MEU, RLT, or BLT level command post SOPs. My expectation is that the MEU level SOPs, in particular, would be comprehensive, and would have detailed discussions of the rapid planning process. I had the opportunity two years ago to watch the MCWL's Special Purpose MAGTF (X) work on their SOPs and was impressed by the technique they used to trace decision threads among multiple locations, particularly for fire support coordination decisions.

[7] The efforts and products of two organizations need to be highlighted. The Marine Corps' MSTP staff has produced a series of "MSTP Pamphlets" addressing a score of command and control topics at a more detailed level than is currently found in the Marine Corps doctrinal publications. In addition, the MSTP staff makes available on their home page the training aids for many of the classes they conduct for MAGTF staffs and other groups, such as classes in the Marine Corps University. The entire set of materials is a valuable resource for persons interested in the human dimension of command and control. Similarly, TRADOC task organized a small group of officers, NCOs and civilians to provide direct support to the FORCE XXI training development effort. Called "Warrior T," the group has published a series high quality training materials designed to assist the training efforts of the 4th Infantry Division, the Army's "First Digitized Division (FDD)," at Fort Hood, TX.

[8] Neither FM 101-5-1 nor MCRP 5-12x contains a definition of the term "battle staff." The term comes up sufficiently frequently that a working definition is useful. DRC has used the following in project reports to ARL. The battle staff is the combination of coordinating and special staff officers and NCOs in a command post or operations center with the functional (e.g., intelligence, operations) and battlefield functional area expertise (FSC, ALO, Combat Engineer) necessary to monitor and assess operations; to provide decision support to the commander during the execution phase of the operation; to provide effective coordination among higher, adjacent, supporting, and subordinate commands; and to provide continuous future operations planning. Normally comprised of the command's senior coordinating and special staff officers, and the other staff officers and NCOs on the current watch in the command post. With respect to sleep cycles, the senior staff members are battle staff members on a 24-hour basis, and are recalled from rest as needed.

[9] The Optimum TTP is an open definition at this point. The TTP could be adequately described in one, two, or more nested documents depending upon the comprehensiveness of the development process.

[10] Persons interested in an electronic copy of the paper, contact the author at JimM@drc.com.

[11] The operational events the team observed were all built around conventional operations, and involved no civilians on the battlefield. But clearly, if civilians had been present, the monitoring would have included changes in civilian situations that affected the unit's ability to accomplish its mission.

[12] The term "assessment" as used here is slightly different from the MSTP use of the term. Here it is meant specifically as the cognitive activity a person directs at a specific situation in order to determine the seriousness of the situation and what should be done to correct it or minimize it.

[13] In fact, commanders make many decisions when they are forward on the battlefield, connected to the operations center by FM voice radio or data communication, or both, or not connected at all.

[14] The unit commander determines the layout of his own TOC. The analyst has seen six different brigade TOC configurations during the on-going ABCS experimentation, and while each was laid out differently, obviously, the functions being performed by the battle staffs were all essentially the same.

[15] The fact is, nobody present—not the participants, the observer-controllers, the analysts—really knew how to process and correctly filter all the information present or not present because it had not been requested. The TTP had not been worked out, and still have not been worked out.

[16] CCIR: the information required by the commander that directly affects his decisions and dictates the successful execution of operational or tactical operations. CCIR normally result in the generation of three types of information requirements: priority intelligence requirements (PIR), essential elements of friendly information (EEFI), and friendly force information requirements (FFIR). In the interest of brevity, definitions of PIR, EEFI, and FFIR are available in MCWP 5-12 series and FM 101-5-1, as well as several of the MSTP pamphlets available at the MSTP home page.

[17] Nonetheless, the idea that proficiencies area as applicable to civilian organizations is interesting and in a sense, makes a prima facia case for their utility.

[18] The psychologist's role is to act as a facilitator and social scientist. With respect to the latter, particularly when the BARS are to be used as performance appraisal instruments, the psychologist ensures proper attention is paid to reliability and validity in both the clustering step and the scaling step.

Situation Awareness in a Knowledge-Centric Command and Control Application Environment

LtCol. Robert Morris
Fort Benning, Georgia

Situational Awareness in Understanding-Centric Operations

LTC (P) Bob Morris
morrisr@benning.army.mil

You Cannot Fight Tomorrow's War's with Today's Equipment

Force XII Anti-Cavalry Support Spear (FASS)

Cost Per FASS: $1.50

New Equipment Training:
1 minute 30 seconds

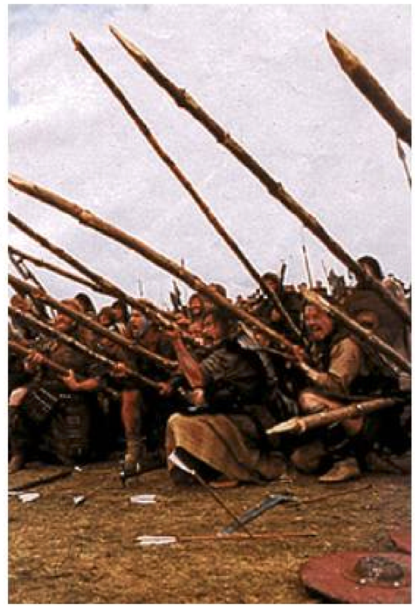
Maintenance:
Periodically sharpen tip,
clean off entrails and blood (as required)

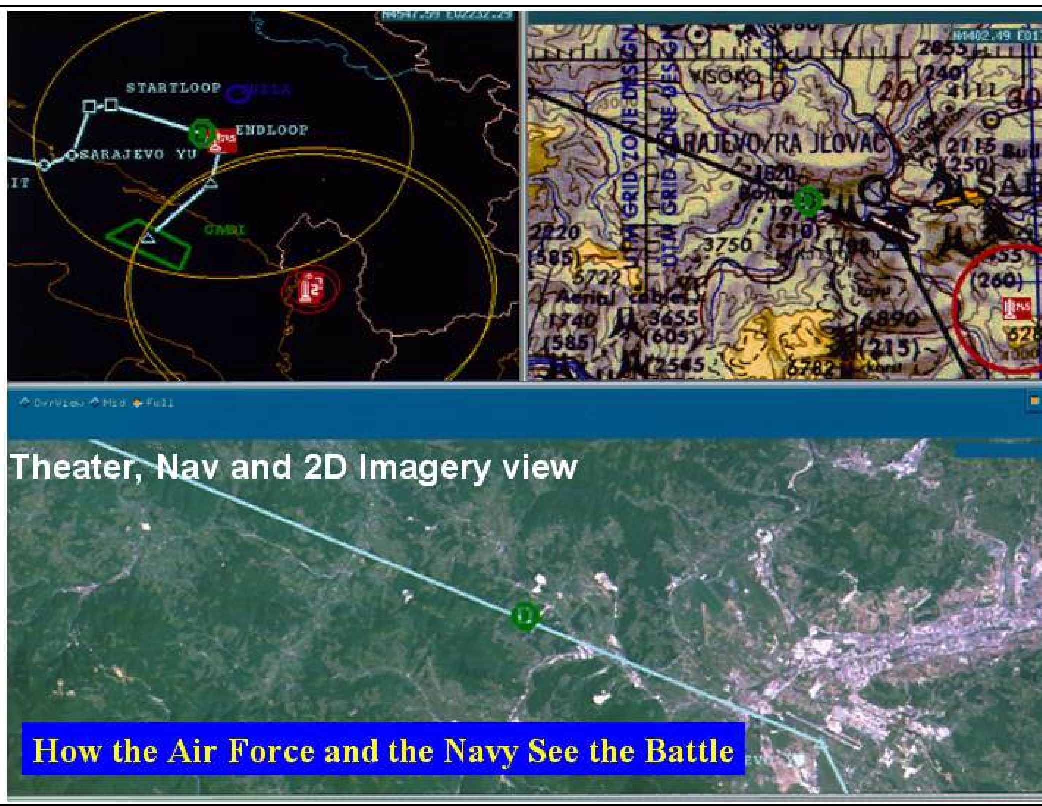
Repairs: None

Experiments : Stirling & Falkirk AWEs

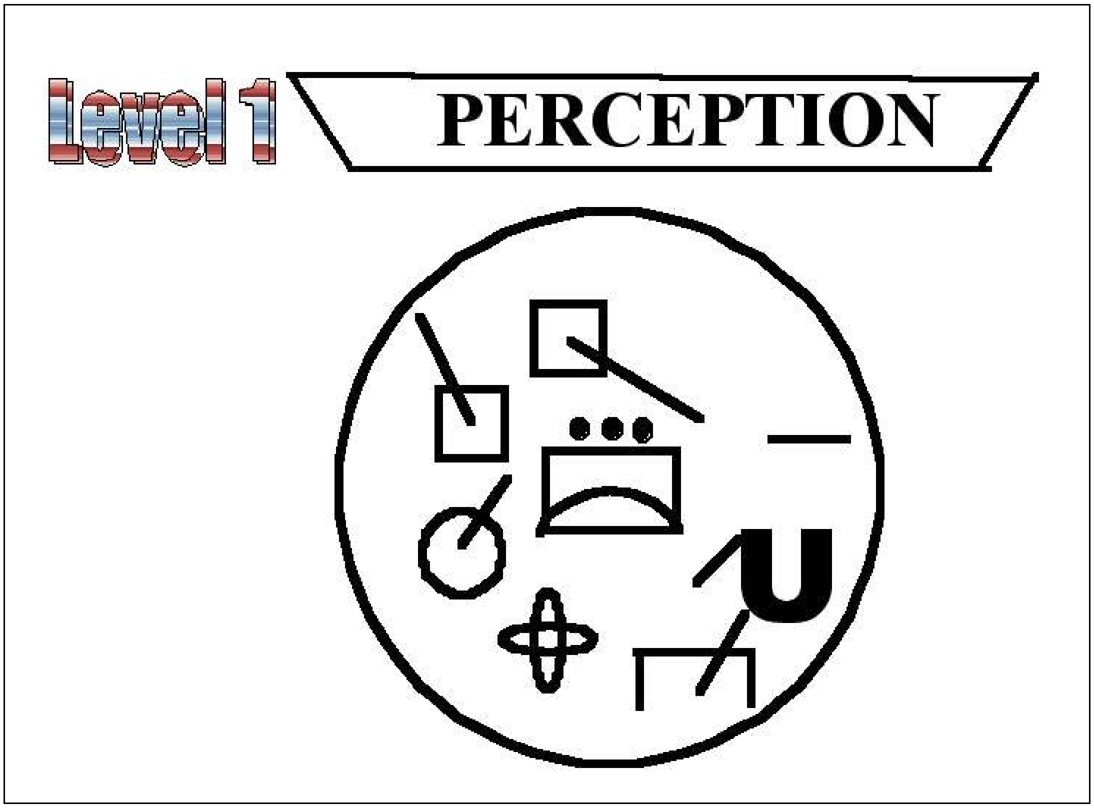
Man Machine Interface:
One man lift & emplacement, splinters,
do not erect in winds over 110 mph

Required Skills: A strong grip, steady
nerves and willingness to die
Program Manager: William Wallace

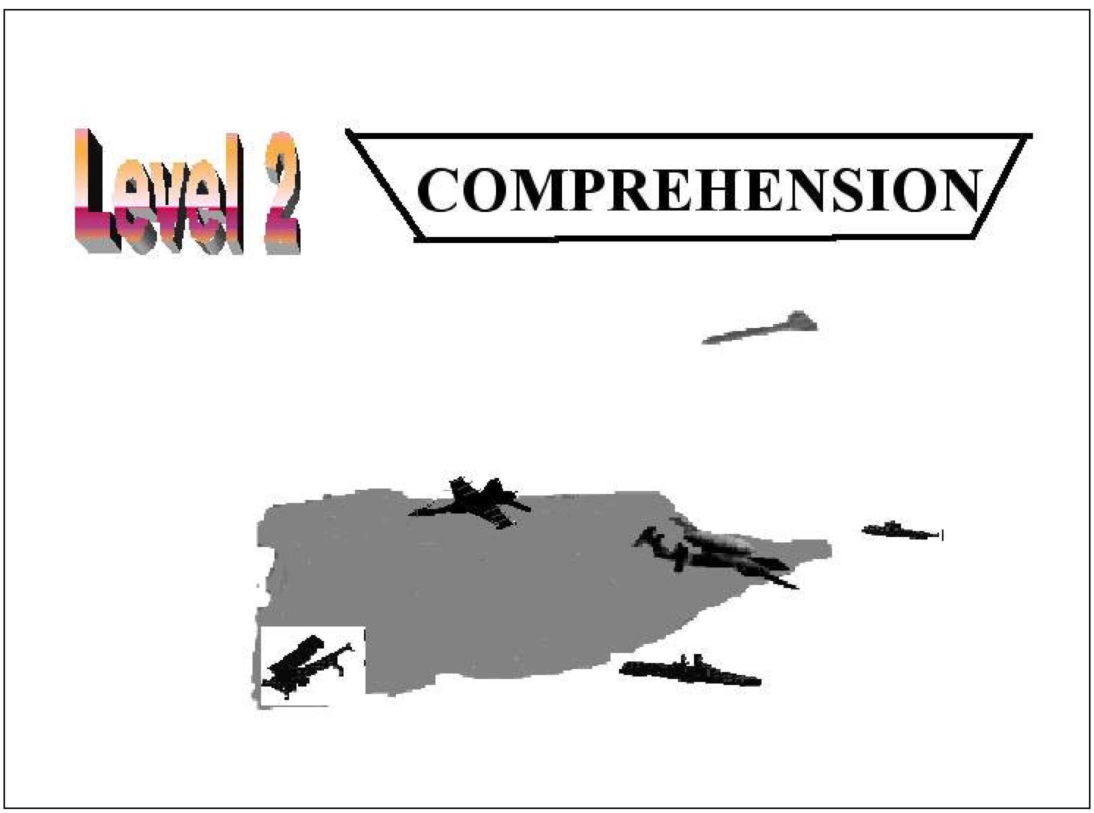




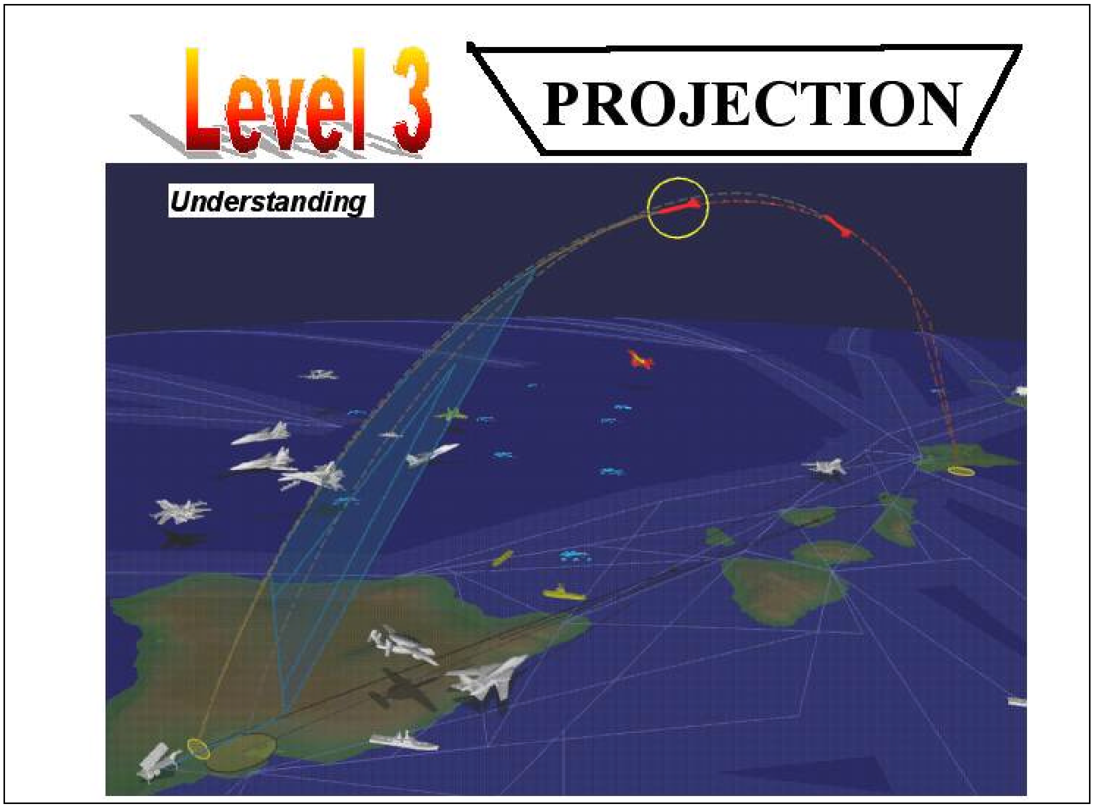
How an INFANTRYMAN Sees the Battle

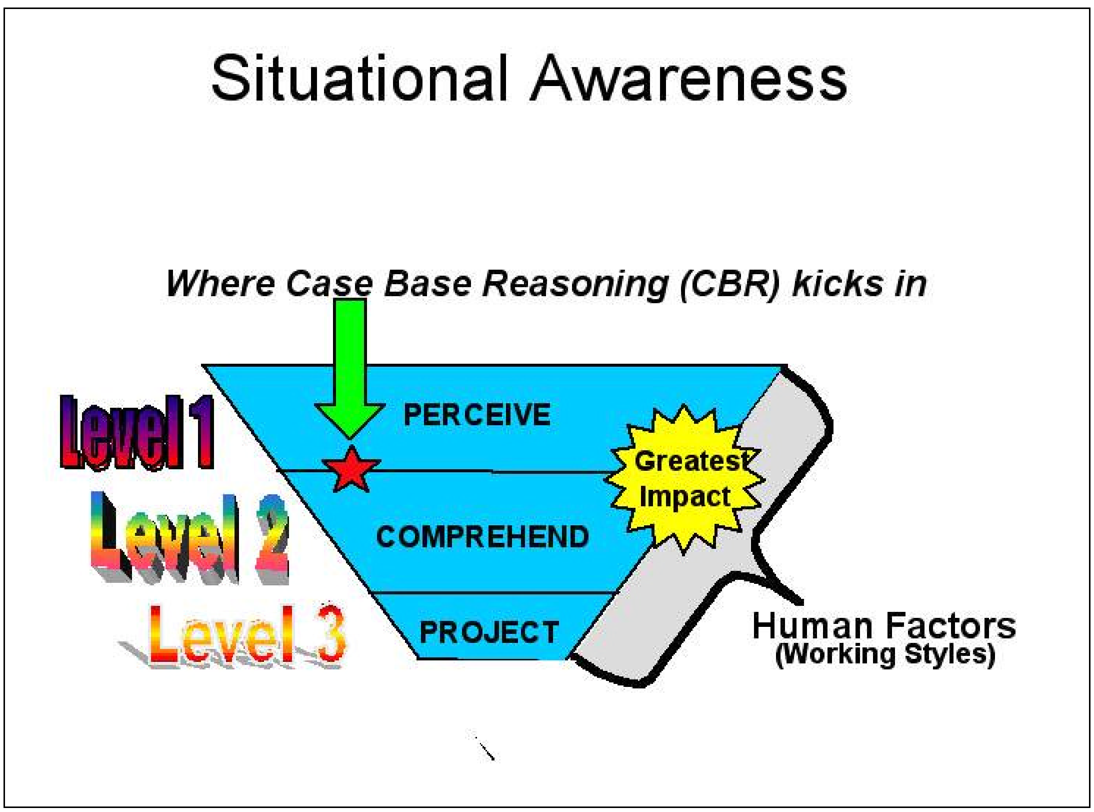


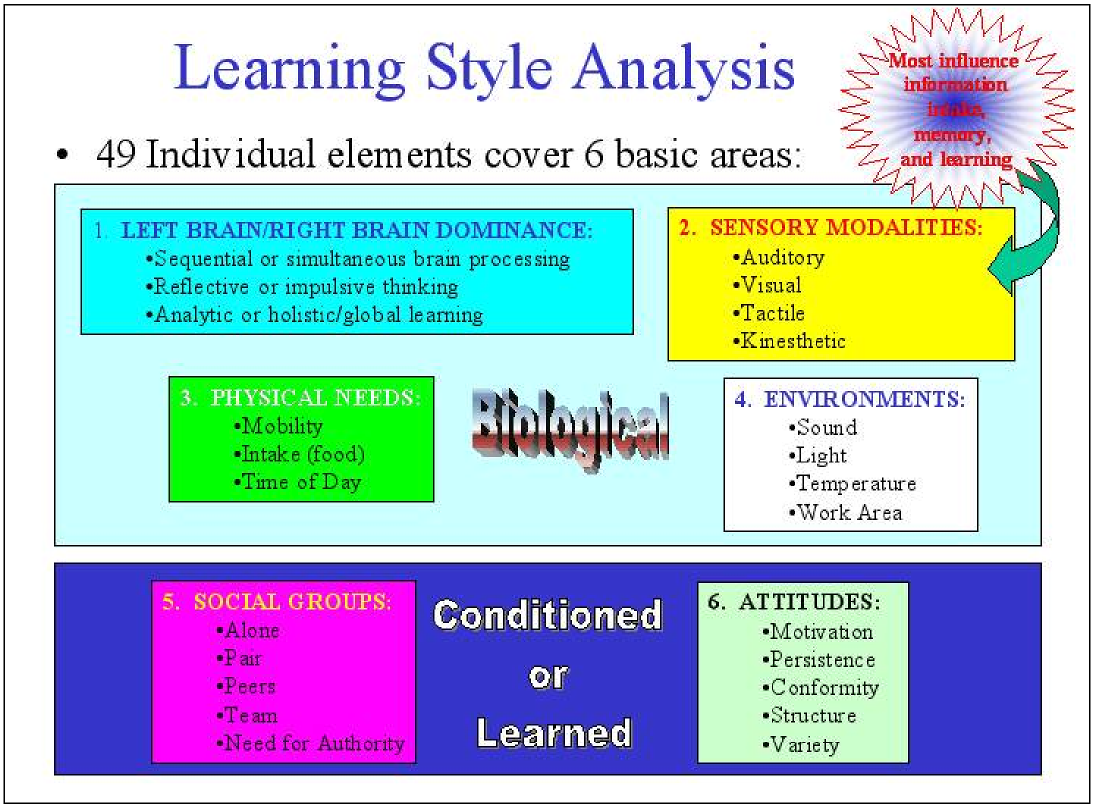
Level 1
PERCEPTION



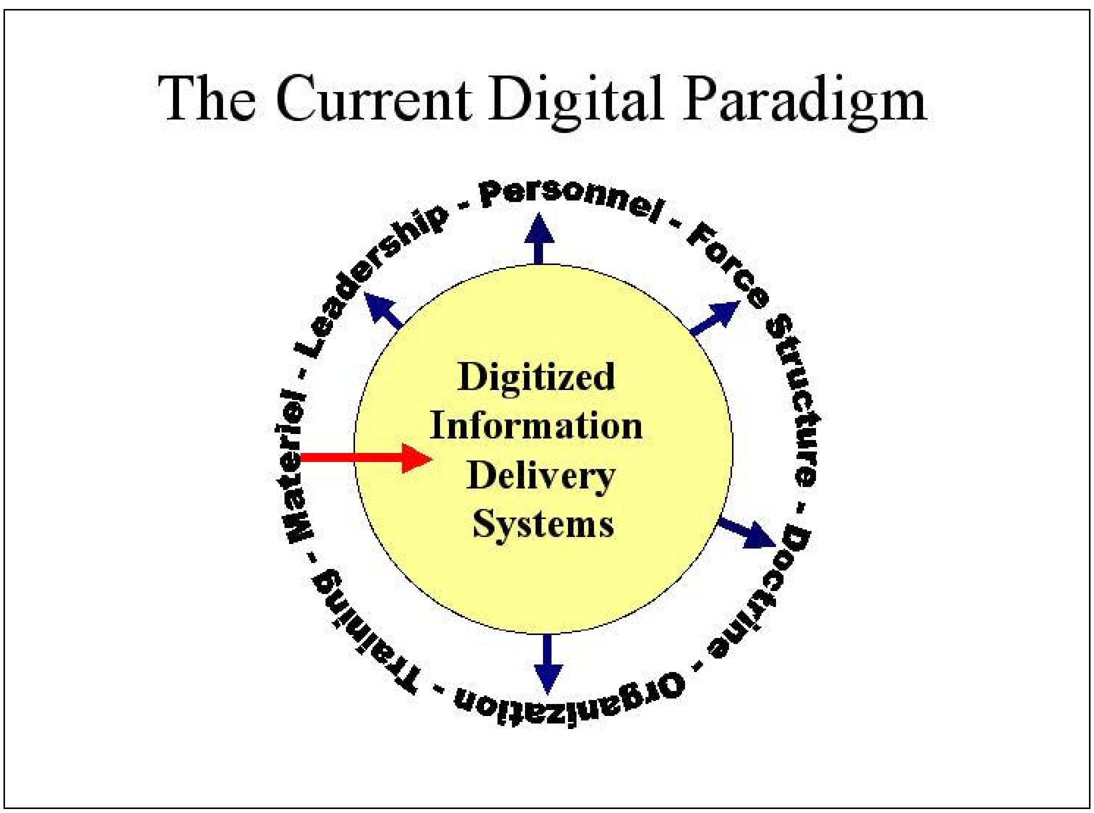
Level 2
COMPREHENSION


Level 3
PROJECTION
Understanding


Situational Awareness
Where Case Base Reasoning (CBR) kicks in
Level 1
Level 2
Level 3
PERCEIVE
COMPREHEND
PROJECT
Greatest Impact
Human Factors
(Working Styles)



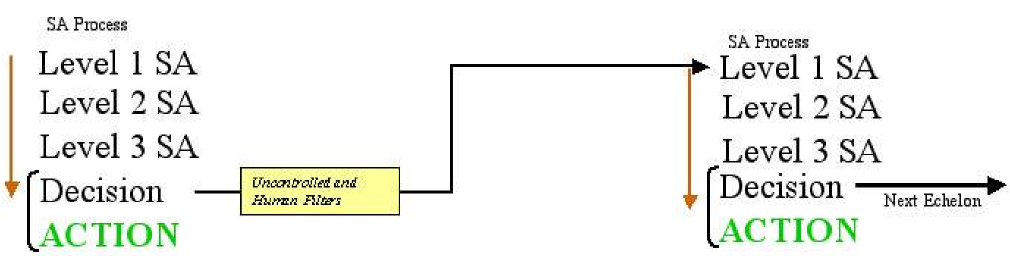
Learning Style Analysis
• 49 Individual elements cover 6 basic areas:
Most influence information intake, memory, and learning
1. LEFT BRAIN/RIGHT BRAIN DOMINANCE:
•Sequential or simultaneous brain processing
•Reflective or impulsive thinking
•Analytic or holistic/global learning
2. SENSORY MODALITIES:
•Auditory
•Visual
•Tactile
•Kinesthetic
3. PHYSICAL NEEDS:
•Mobility
•Intake (food)
•Time of Day
Biological
4. ENVIRONMENTS:
•Sound
•Light
•Temperature
•Work Area
5. SOCIAL GROUPS:
•Alone
•Pair
•Peers
•Team
•Need for Authority
Conditioned or Learned
6. ATTITUDES:
•Motivation
•Persistence
•Conformity
•Structure
•Variety

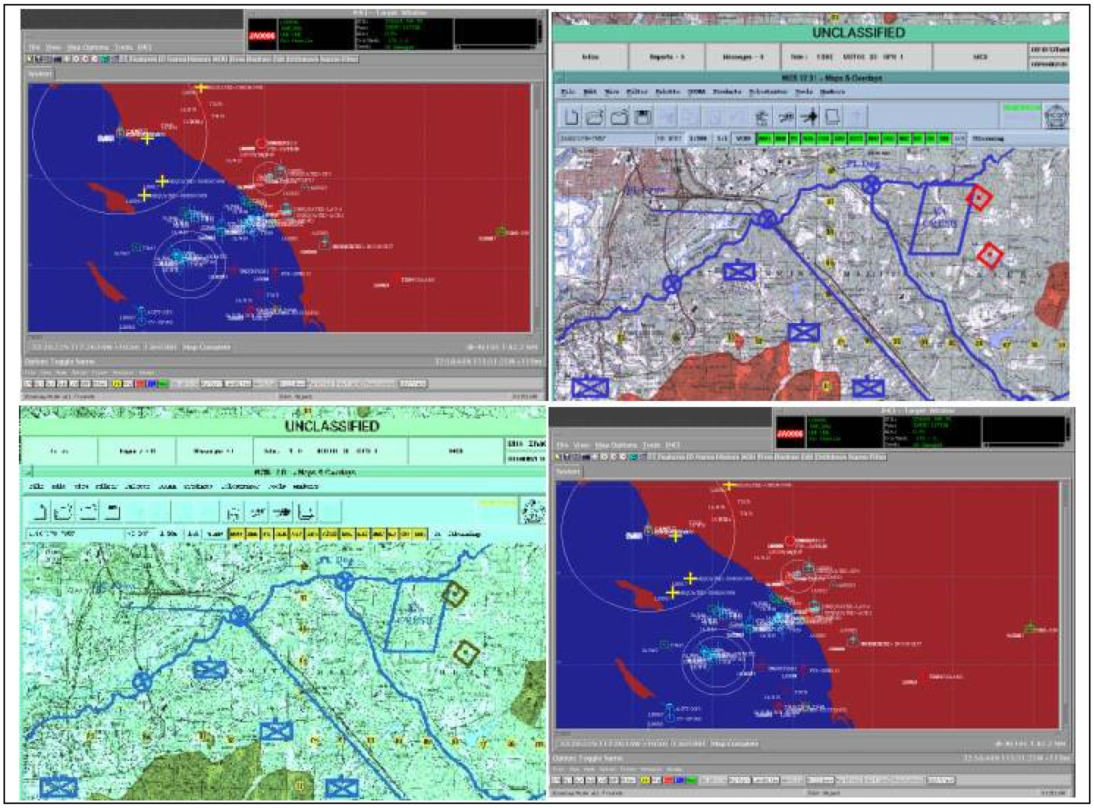


The Current Digital Paradigm
Personnel - Force Structure - Doctrine - Organization - Training - Materiel - Leadership -
Digitized Information Delivery Systems

Conceptual Myths based on Recent Evaluation findings

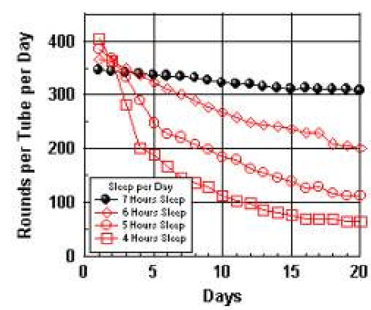
- Information delivery is information understanding.
- Warfighters in combat stop using digital systems due to a lack of Warfighter discipline or training.
- Warfighters think about the same problems the same way.
- Digital system failure can be eliminated with TTPs.
- Digitization will reduce the use of voice radios.
- A "standard" computer interface will support the entire force.
- Situational Awareness (SA) is the amount of information delivered to a digital system.





Degrading Cognitive Readiness

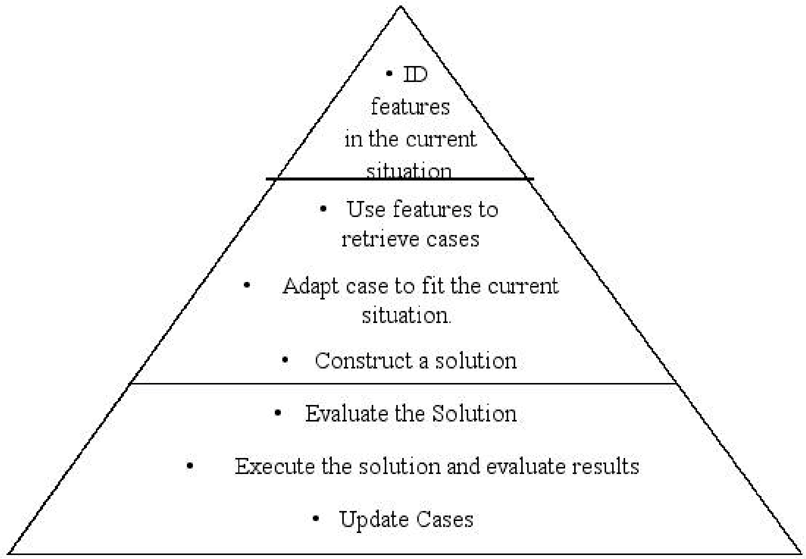
- Sleep deprivation degrades cognitive performance linearly while normal amounts of sleep sustain performance indefinitely.
- Less than normal amounts of sleep degrade performance.
- The recent Army JCF AWE showed **the amount of sleep deprivation in Warfighters using digital systems is approaching that of their leaders.**



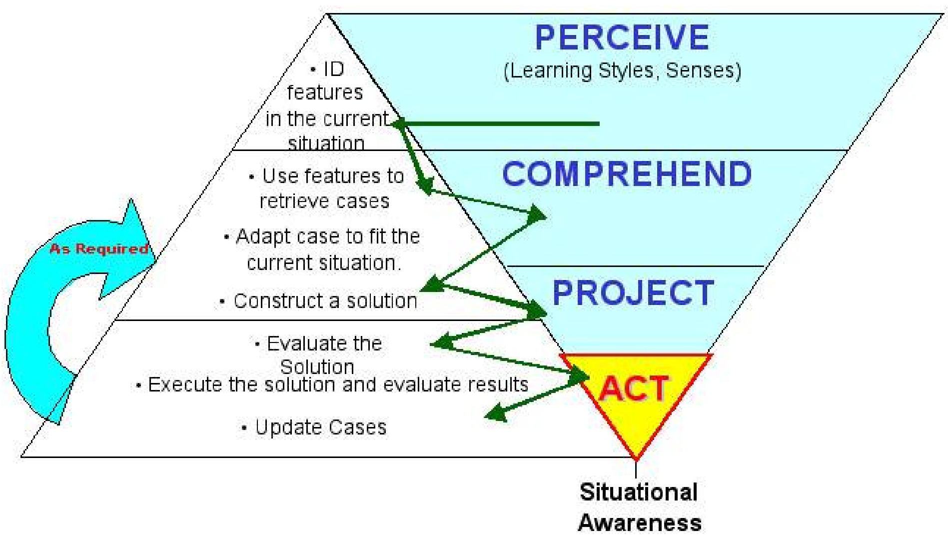
Department of Behavioral Biology
Walter Reed Army Institute of Research

Impact will increase with the proliferation of digital systems to the warfighter level.

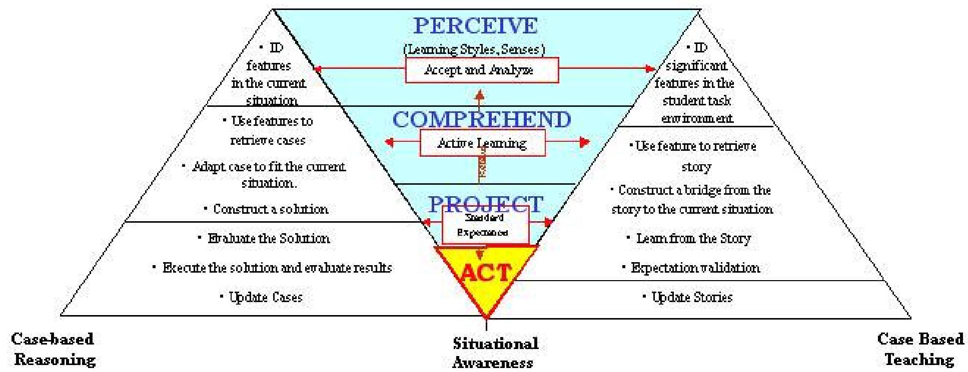
CASE BASED REASONING



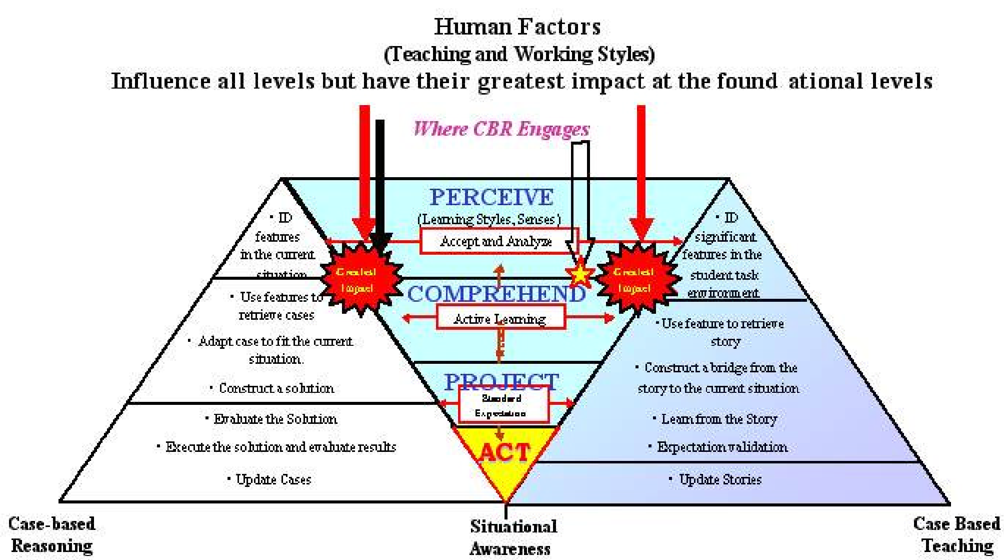
Case-Based Reasoning and SA



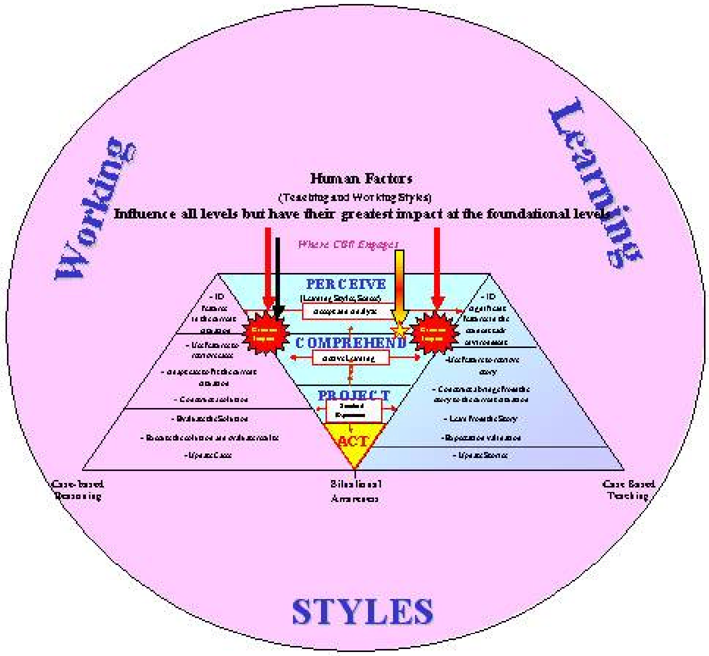
Information In, Information Out...



The Human Element



The Human Dimension



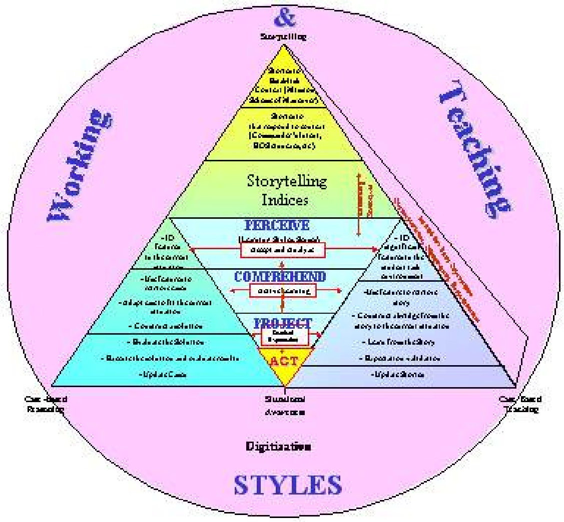
Conveying Understanding

It isn’t Magic……

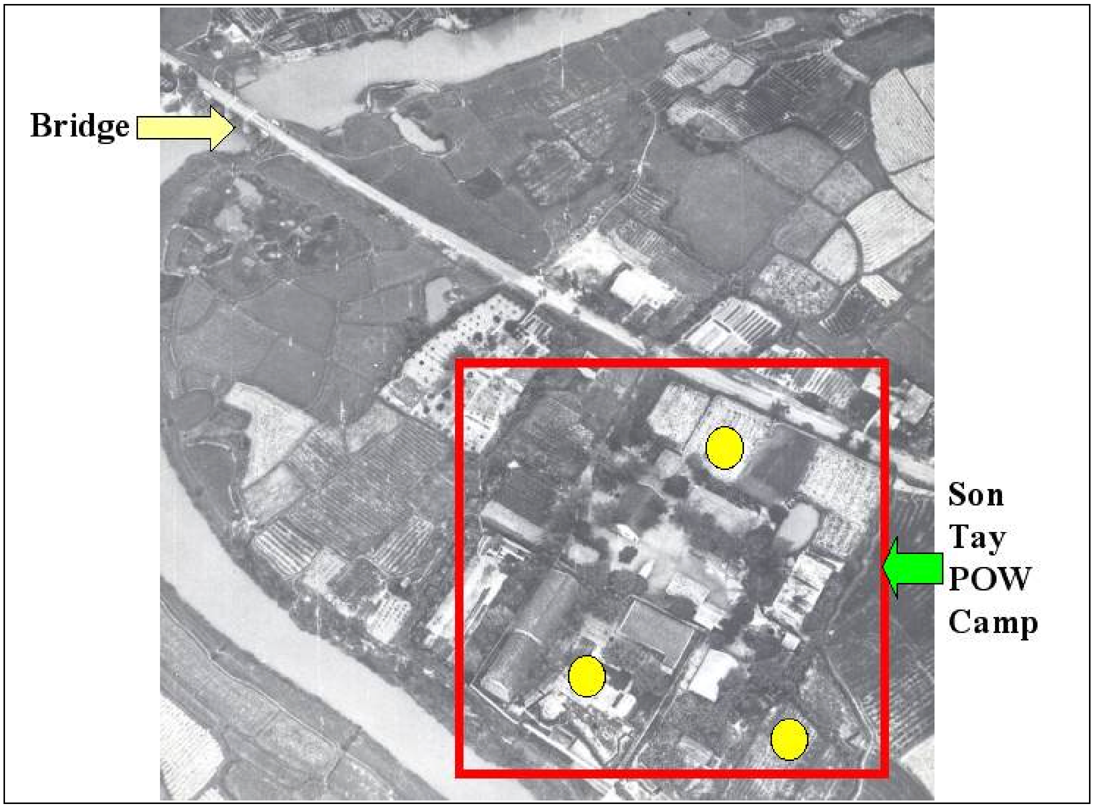
It’s Just a ***Story***……

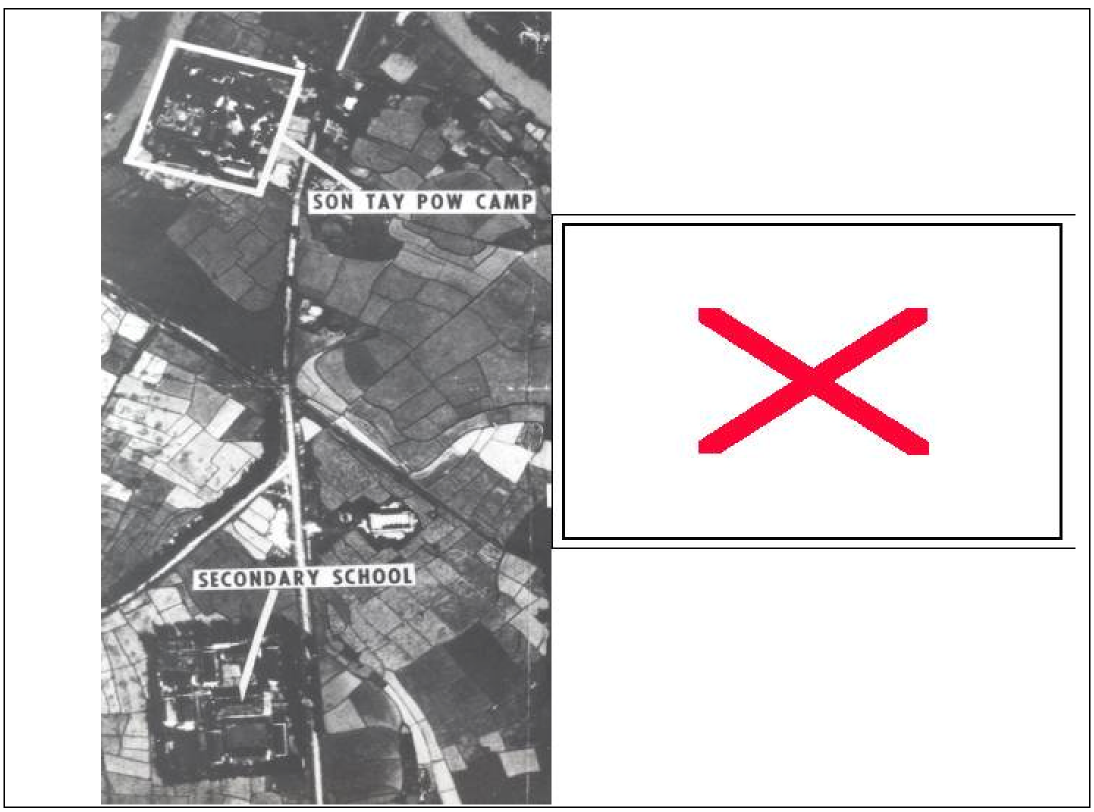
We don’t care if you get the order, We only care if you UNDERSTAND the order

Getting the Information there...

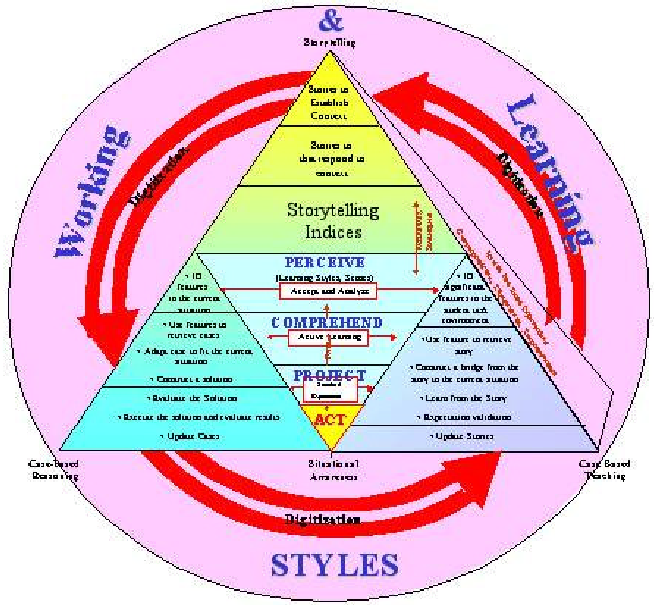


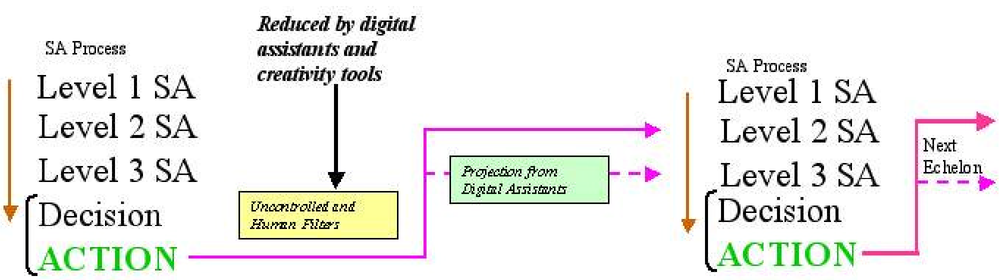
One Night in Vietnam


Bridge
Son Tay POW Camp


SON TAY POW CAMP
SECONDARY SCHOOL

The Role of Digitization

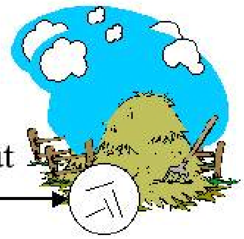




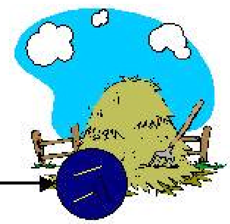
Information is a haystack…

The right information to the right person at precisely the time it's needed

All you really care about are the needles



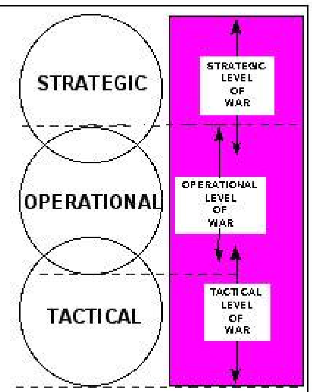
What you really need are the *GOLDEN* needles

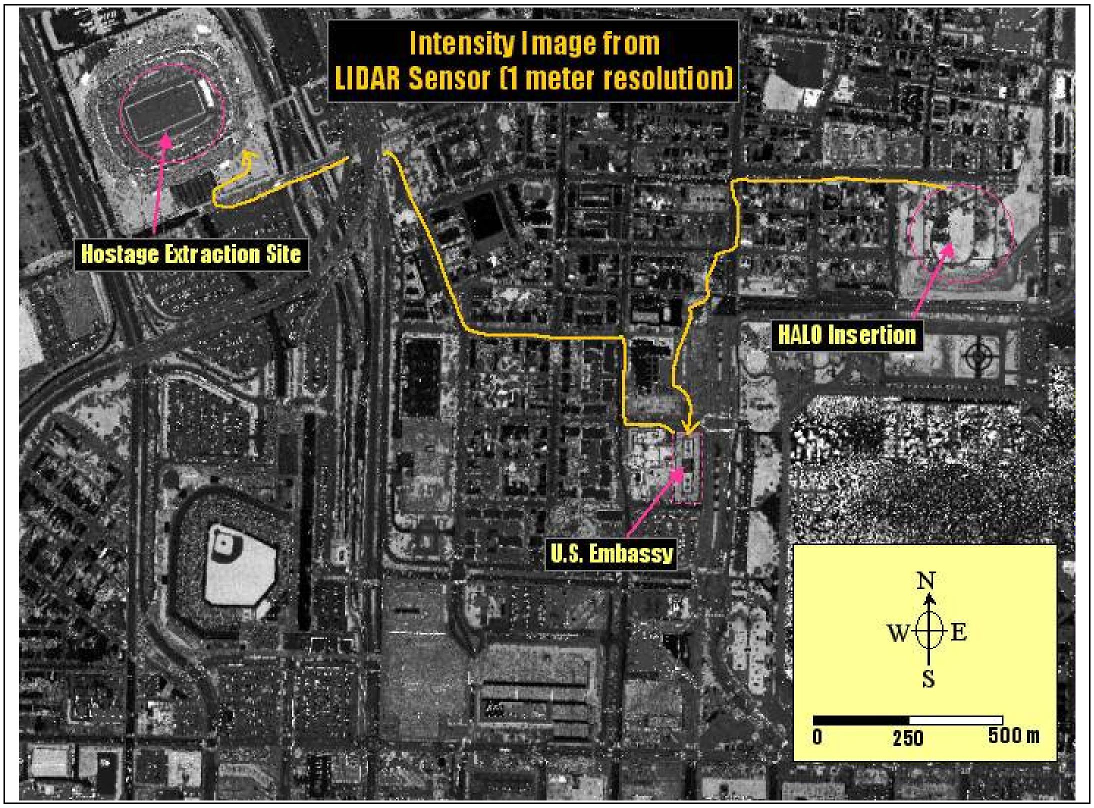


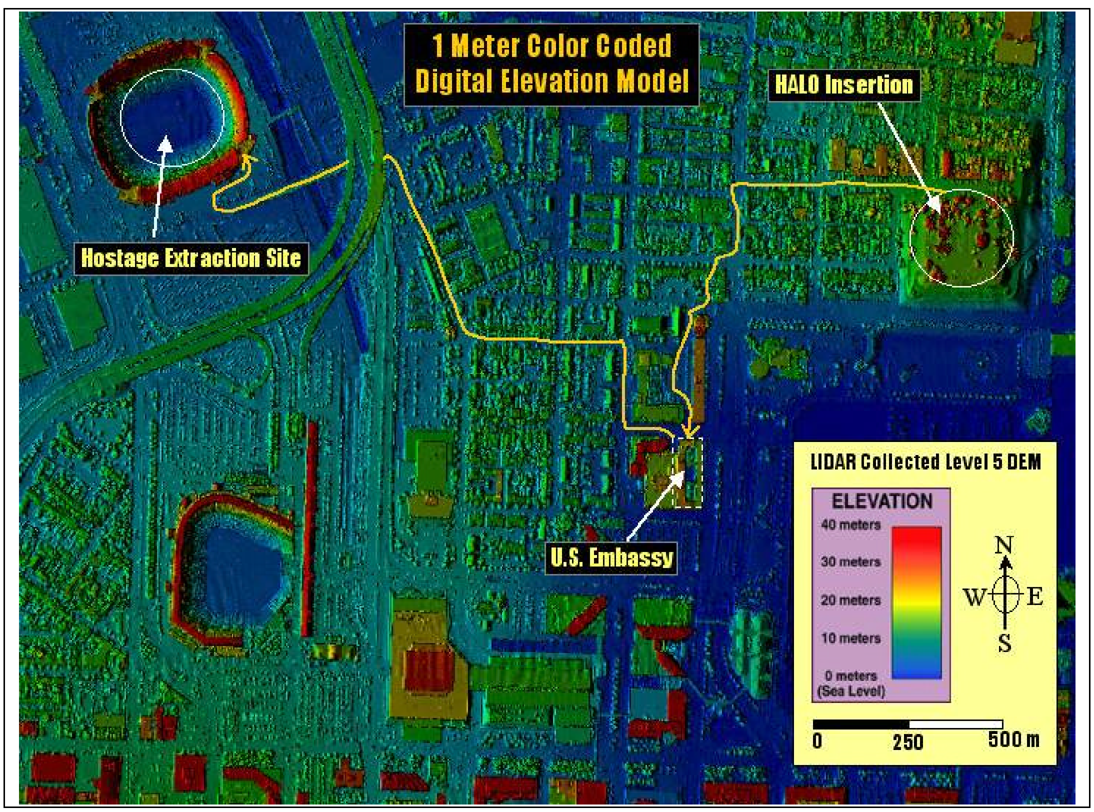
BUT YOU SHOULD NOT HAVE TO FIND THEM YOURSELF !

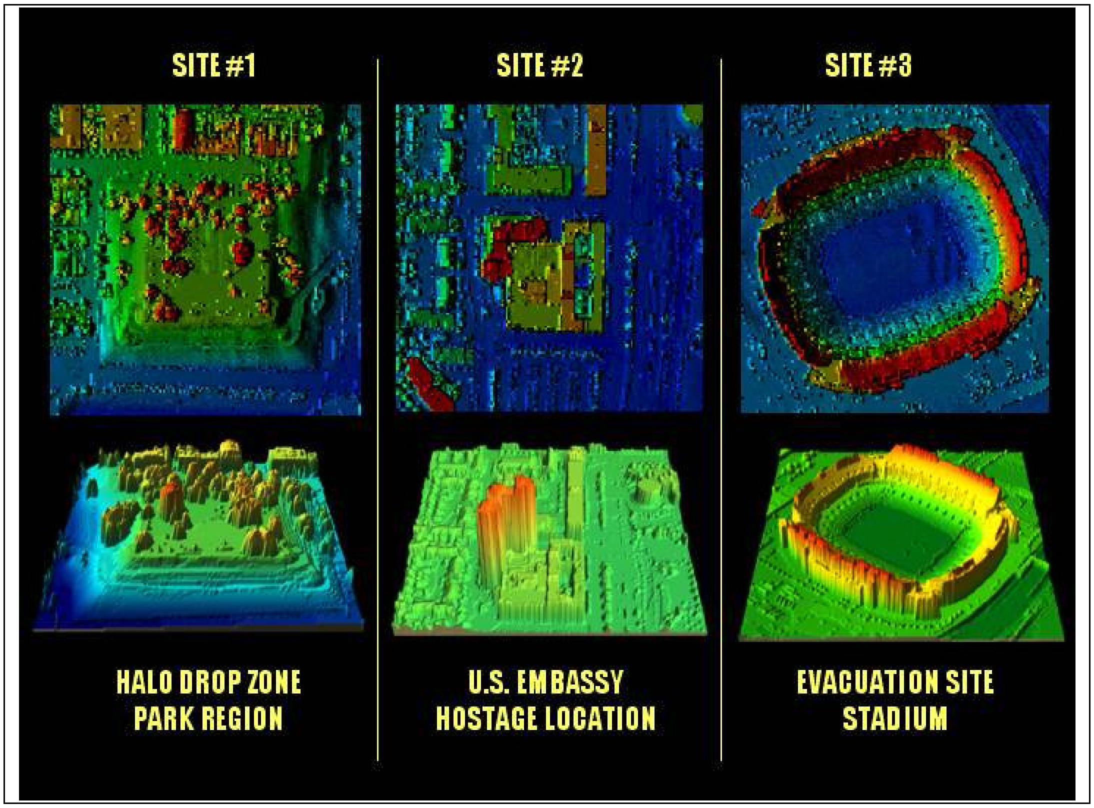
Enabling Level 3 SA

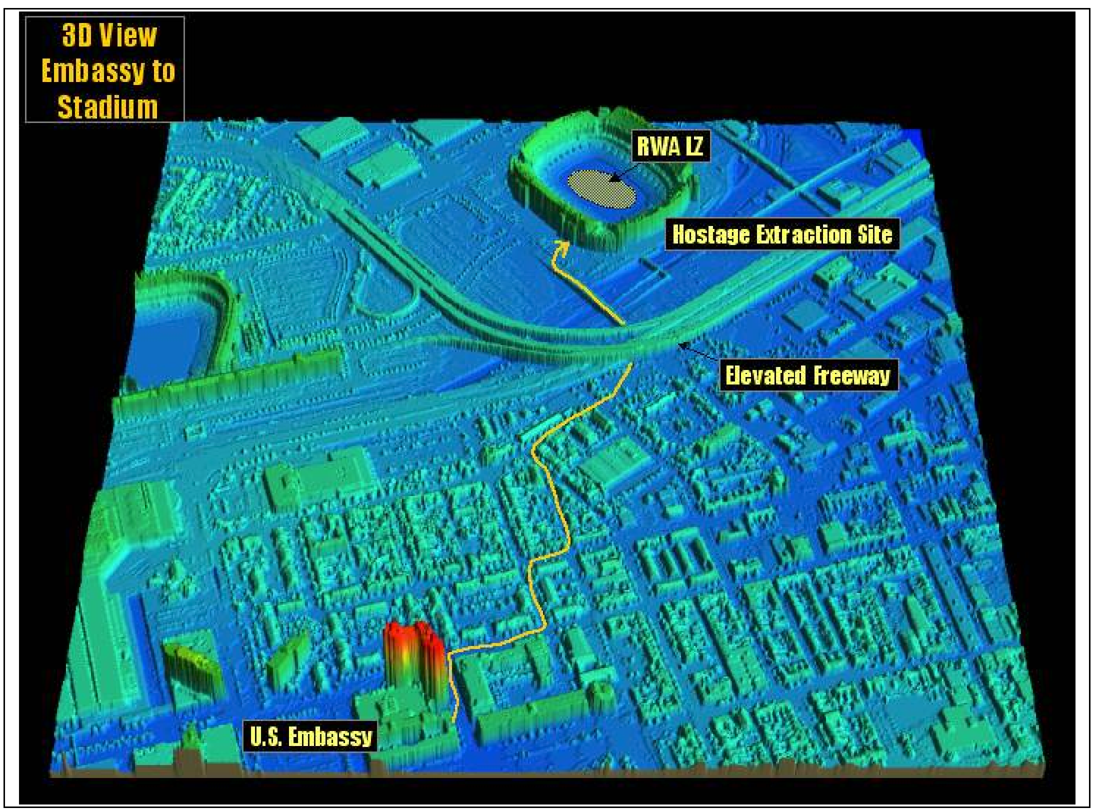
1a. Help the Terrorist achieve their goal of obtaining a separate state.
1b. Persuade them they don't need a separate state.
2. Adopt the methods of the terrorists.
3a. Improve living conditions in refugee camps; try building a public housing project.
3b. Get them out of the refugee camps.
4. Kill or arrest the terrorists.
5. Assassinate or arrest their leader
6. Employ a former terrorist as an advisor on counter -terrorism.
7. Censor news reports of the terrorist activities.
8. Destroy their political power; try bribing their leaders
9. Do nothing: the terrorists will self -destruct.
10. Get the terrorists' religious leaders to denounce terrorism .

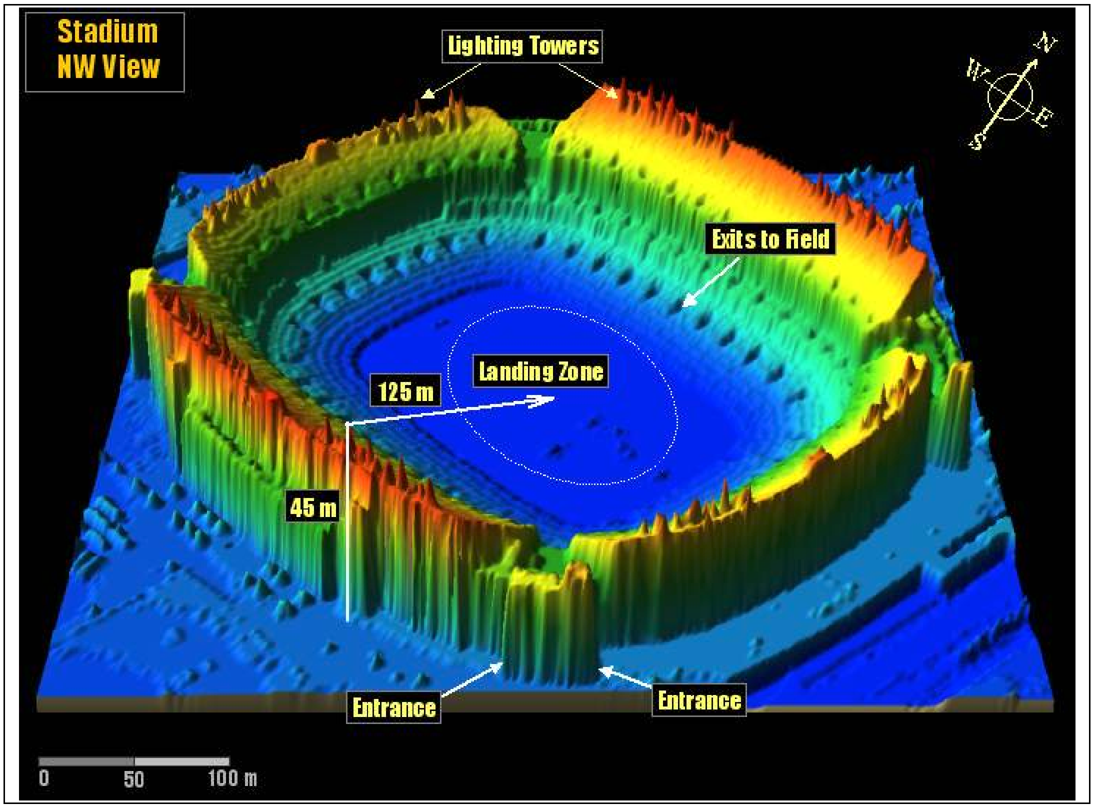


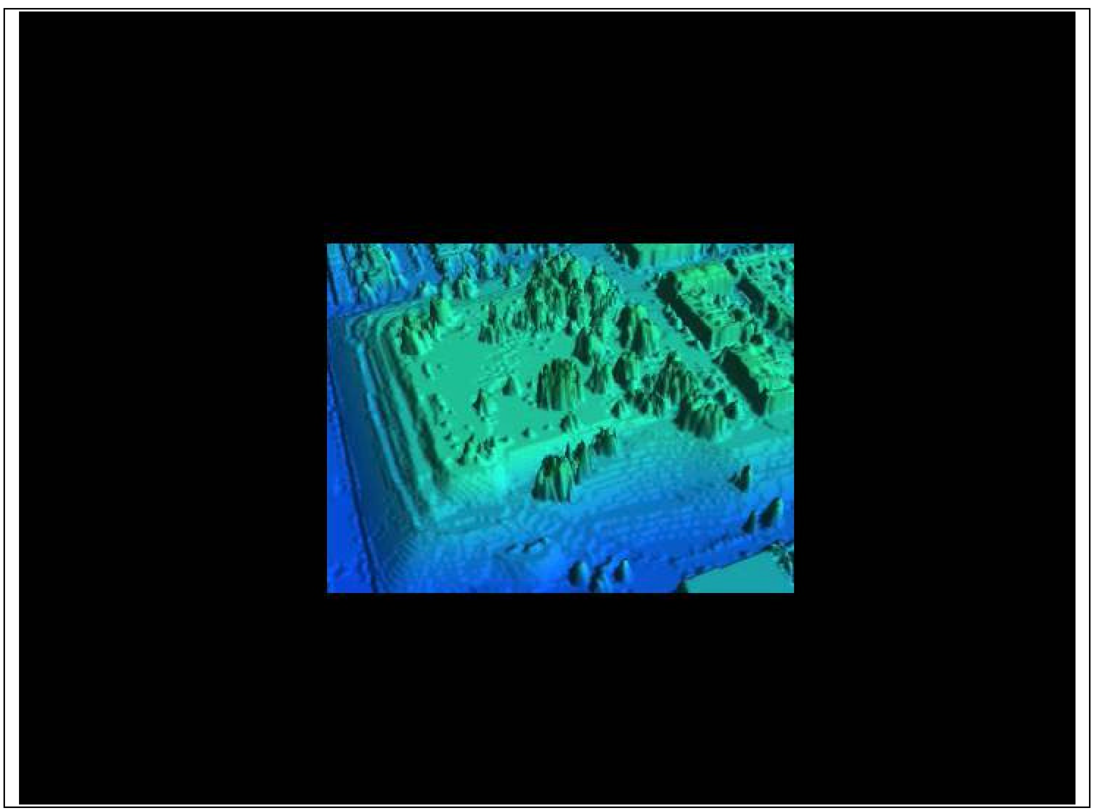

Intensity Image from
LIDAR Sensor (1 meter resolution)
Hostage Extraction Site
HALO Insertion
U.S. Embassy
N
W
E
S
0
250
500 m


1 Meter Color Coded
Digital Elevation Model
HALO Insertion
Hostage Extraction Site
U.S. Embassy
LIDAR Collected Level 5 DEM
ELEVATION
40 meters
30 meters
20 meters
10 meters
0 meters
(Sea Level)
N
W
E
S
0
250
500 m

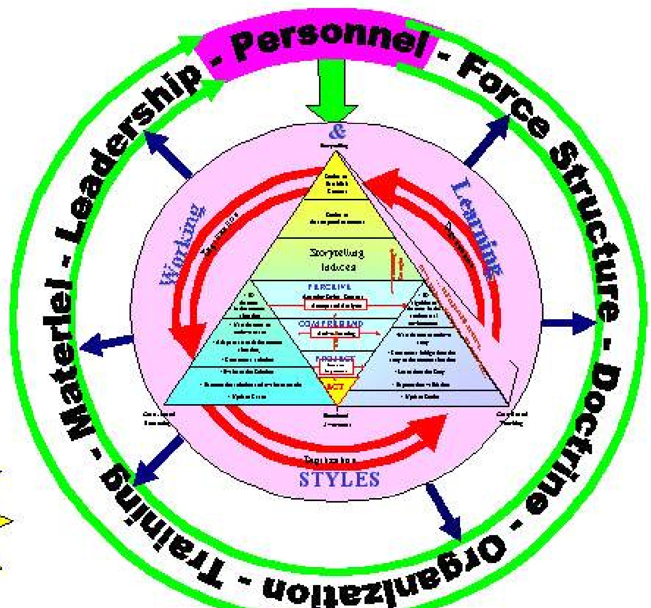

SITE #1
SITE #2
SITE #3
HALO DROP ZONE
PARK REGION
U.S. EMBASSY
HOSTAGE LOCATION
EVACUATION SITE
STADIUM


3D View
Embassy to
Stadium
RWA LZ
Hostage Extraction Site
Elevated Freeway
U.S. Embassy


Stadium
NW View
Lighting Towers
N
W
E
S
Exits to Field
Landing Zone
125 m
45 m
Entrance
Entrance
0
50
100 m



The New IT Paradigm



Engineer systems to warfighters, not engineering warfighters to systems

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Joint Cognitive Ability and Readiness Measurement and Analysis (JCARMA) JT&E Proposal

- Understanding is Out There - JCARMA

"Situational Awareness from understanding-based systems"

How will we know we achieved it?

The Problem

Current Test Methodologies inadequately evaluate, assess and measure the Situational Awareness (SA) gained by the joint operational to tactical level warfighter from currently fielded to future Information Technology (IT) systems.

Solution: **A testing and evaluation methodology to assess understanding, Situational Awareness and information delivery.**

"Having access to that information quicker than the adversary is becoming more important because he who acts quickest wins" - Brig. Gen. Bell, J6, USJFCOM

***"...advances in information capabilities are proceeding so rapidly that there is a risk of outstripping our ability to capture ideas, formulate operational concepts, and develop the capacity to assess results."* – JV2020**

Potential Test Issues

- JCARMA seeks to determine:
  - To what extent and level of validity can an understanding based methodology assess the contribution of IT systems to the SA of military members during joint operations?
  - To what extent can an enhanced SA measurement methodology be used to help develop the hypotheses, objectives, and dendritics for operational tests and evaluation?
  - To what extent can the influence and relationship of individual and group reasoning, working and learning styles under stress and non-stress conditions on the success of IT systems in providing SA be determined?

"Command and control systems must provide landing force commanders at all echelons a common operational picture and the connectivity to monitor execution and to influence events when necessary."

United States Marine Corps Emerging Operational Concepts

Objectives

- Develop and validate a standard joint methodology for assessing SA of military members and organizations during joint operations.
- Develop a military member SA schema that contributes to the assessment of IT systems contribution to SA
- Develop a military member working, learning and reasoning style profile under stressed and unstressed conditions

"They must be able to request and receive specific, real-time, and near- real-time information in a usable format, whether they are embarked, maneuvering toward objectives, or conducting operations ashore."

United States Marine Corps Emerging Operational Concepts

Test Program

- JFS: Aug 01 - Aug 02
- Develop Program Test Plan: Aug 02 - Aug 03
- Standup Joint Test Facility: Aug 02 - Jun 03
- Small Scale testing and analysis: Aug 03 - Jul 04
- Large Scale testing and analysis: Jul 04 - Jul 05
- Finalize repository and data base: Jul 06
- Final report/Joint Test Facility closes: Sep 06

Each major test phase will also have a report, due 120 after completion of testing.

Status of Support

Organization	Service	Coordination	Brief	Concurrence
OSD (AS&T)	DOD	✓	✓	✓ - Written (Mr Eash)
OSD (P&R)	DOD	✓	✓	✓ - Written (Dir, R&T)
OSD (S&T)	DOD	✓	✓	Positive Comments
DMSO	DOD	✓	✓	✓ - Written (Col Crain)
Smart Sensor Web	DOD	✓	✓	✓ - Written (LTC Bjorkman)
DOT&E	DOD	✓		In Progress
USJFCOM	JOINT	✓	✓	✓ - Written (MG CASH)
USCINCPAC	JOINT	✓	✓	In Progress
USSOCOM	JOINT	✓	✓	Supportive
USCINCTRANS	JOINT	✓	✓	- Awaitng Letter
JSOC	JOINT	✓	✓	Positive Comments
Dom. Mnvr. JWCA	JOINT	✓	✓	Positive Comments
IDA, (JAWP)	JOINT	✓	✓	Supportive
JITC	JOINT	✓		Brief 15-17 May at TAB
JNTF	JOINT	✓		Brief 15-17 May
MCWL	USMC	✓		In Progress
MCCDC	USMC	✓	✓	Strong Support
MCOTEA	USMC	✓		In Progress
MARFORPAC	USMC	✓	✓	✓ - Written (LTG LIBUTTI)
MARCORSYSCOM	USMC	✓	✓	✓ Drafting Letter

Status of Support

Organization	Service	Coordination	Brief	Concurrence
SPAWAR	USN	✓	✓	✓ - Written (CAPT Shelton)
ELB ACTD	USN	✓	✓	Supportive
COMOPTEVFOR	USN	✓	✓	Briefed, Positive Comments
ONR	USN	✓	✓	Pos comments
NAVAIR	USN	✓	✓	Supportive, brief TBD
PEO-SURFACE STRIKE	USN	✓	✓	✓ - Written (Mr Bost)
AC2ISR	USAF	✓		In Progress
AFRL	USAF	✓		Files sent to staff
AMC Experimentation Branch	USAF	✓	✓	In Progress
AFOTEC	USAF	✓	✓	✓ - Written (Dir, Test Support)
DUSA (OR)	ARMY	✓	✓	Positive Comments
DA DCSPER	ARMY	✓	✓	Working Letter
ASA (ALT)	ARMY	✓	✓	✓ - Written (Dr Dubin)
USAMC	ARMY	✓	✓	Email to SCI Advisors
ATEC	ARMY	✓	✓	✓ Written (Mr Apicella)
ATEC	ARMY	✓	✓	✓ Written (MG Marcello)
FORSCOM	ARMY	✓	✓	Working Letter
XVIII ABC	ARMY	✓	✓	✓ - Written (BG Petraeus)
USARPAC	ARMY	✓	✓	Brief 14 June (T)
TRADOC HQ	ARMY	✓	✓	✓ - Written (Mr Resnick)
USAIC	ARMY	✓	✓	✓ - Written (MG LeMoyne)
ARL HRED	ARMY	✓	✓	✓ - Written (Dr Keese)

Status of Support

Organization	Service	Coordination	Brief	Concurrence
ARL CISD	ARMY	✓	✓	✓ - Written (Mr Gantt)
ARL-HOOD	ARMY	✓	✓	✓ - Written (Mr. Smootz)
Walter Reed	ARMY	✓	✓	✓
Canadian Armed Forces	Coalition Army	✓	✓	✓ In Progress
New Zealand Defense Forces	Coalition Army/Navy	✓	✓	Draft Letter in New Zealand
United Kingdom Forces	Coalition Army/Navy	✓	✓	
Cal-Polytech	CIV	✓	✓	✓ Written (DR Pohl)
Univ of Auckland	CIV	✓	✓	✓ Written (Mrs. Woods)
Dr. Mica Endsley	CIV	✓	✓	✓ Written (Dr Endsley)

JCARMA Summary

- **Written support and commitments throughout the Joint World:**
  - DOD (4) - USA (9) - USMC (3)
  - CINCs (2) - USN (3) - USAF (1)
  - Private Sector (2 world recognized experts)

And Increasing!

- **Importance to the T&E Community:**
  - AFOTEC will provide SME support.
  - ATEC ***will provide funding*** and SME support to derive immediate benefits.
- **Direct impact to the warfighter:**
  - Lethality, survivability, adaptability and decision superiority require SA.
  - Ensures IT systems are a benefit not a burden.
  - Superior knowledge that enables faster decisions.
- **Impact on current/future high investment SA systems (a sample):**
  - $750M Human Factors program (Navy/USMC) – Desires JCARMA metrics
  - DD-21 (Navy) – Desires JCARMA metrics
  - Information for Global Reach (USAF) – require metrics
- **Valuable, Immediate Secondary Spin-Offs:**
  - DMSO ***will provide funding*** to derive secondary benefits.
  - Training, Requirement Development, System Design and TTPs

JCARMA Supporters

A ***sample*** of the broad-based support

- **Importance to T&E Communities**
  - **ATEC - MG Marcello** "ATEC is willing to commit funding and support with subject matter expertise in order to derive immediate benefits…" "Provides… a methodology in areas that have become increasingly more important…"
  - **AFOTEC - Col Siler - Dir. Test Support** "The JCARMA methodology once developed can be used in future AFOTEC OT&Es…We feel the project is worthwhile"
- **Direct impact to Warfighting Commands**
  - **USJFCOM -MG Cash** "…significantly benefits J9's efforts in military transformation and enhance quality of our independent Joint assessments."
  - **CINCTRANS – Gen Robertson** "I'll get it to my futurists and IT guys"
    - **RADM Fahy (J5)** "We like your proposal and will work with you"
  - **MARFORPAC - LtGen Libutti** "…nomination is absolutely on target and critically needed."
  - **XVIII Abn Corps - BG Petraeus** "…potential to improve the operational commander's go-to-war capabilities by improving Situational Awareness."
- **Material Development Commands**
  - **PEO Sea Strike - Bob Bost (Dir, Optimal Manning, DD21)** "…we can definitely team up with this nomination"
  - **SPAWAR - CAPT Shelton** "This is an evaluation problem that crosses service boundaries and is made more imperative by increasing Joint operations", "CINC 21 depends on the measurement of cognitive performance."

The Help We Need

- Support for Program Development:
  - Support a Joint Working Group
  - Use the results/Products
  - Letter of Support to assist in obtaining OSD program approval at the final board this summer.
  - Identify Joint and service programs that can benefit from or partner with JCARMA
- Team in Building the Methodology

ftp://192.153.150.25/dbbl/JCARMA%20JT_E/Proposal/

For further information contact LTC(P) Morris at e-mail:morrisr@benning.army.mil Or Call Capt Litwhiler @ (706) 545-9620

Perspective Filters as a Means for Interoperability Among Information-Centric Decision-Support Systems

By
Kym J. Pohl
Collaborative Agent Design Research Center (CADRC)
California Polytechnic University
San Luis Obispo, California
kpohl@cadrc.calpoly.edu

If the key to symbolic reasoning is representation then it certainly follows that the foundation of expert-system-based, decision-support systems is the rich manner in which the entities, concepts, and notions relevant to the domain space(s) are represented [4, 10]. This requirement can be accommodated through the development and employment of one or more ontologies. An ontology in this sense can be defined as a relationship-rich, typically object-based representation of the entities, concepts, and notions relevant to the domain(s) of operation. The problem arises when two or more of these systems, each operating over a potentially extensive ontology attempt to collaborate with each other. While collaboration within each of these systems may be based on very high-level descriptions of entities, concepts and notions, it will undoubtedly be subject to various application-specific biases. For example, in a tactical command and control system an entity such as an M1A1 tank may be viewed, and therefore represented as a tactical asset. In this case the bias would be toward tactical utility. However, in a logistics system the same M1A1 tank would most appropriately be viewed as a potential supply item with emphasis on logistical inventory and supply. In both cases, however, the subject is still the exact same M1A1 tank with basic characteristics. The difference resides in the manner in which the tank is being viewed by each of these systems. Another term for this bias-based filter is *perspective*. Perspective is not only a natural component of the way in which we perceive the world but moreover should be viewed as a highly beneficial and desirable characteristic. Perspective is the ingredient in an ontology-based decision-support system that allows for the representation of domain-specific notions and bias. For example, if a decision-support system is to assist in the formulation of logistical supply missions then it is more appropriate, and beneficial for an entity such as a howitzer to be primarily viewed as a supply item instead of a tactical asset. If viewed as a supply item the description of a howitzer could provide great detail in terms of the items shipping weight, shipping dimensions, tie-down points, etc. In the context of a tactical command and control system such information is essentially irrelevant and certainly not of primary focus. What would be relevant in such a tactical system would be characteristics such as projectile range, effective casualty radius, advancement velocity, etc. Again, it may be the exact same howitzer that is being discussed between the two disparate systems. However, it is being discussed within two different contexts exhibiting two distinctly different perspectives. While collaboration within or across systems supported by the exact same perspective-based representation performs well, the problem arises when collaboration needs to occur between systems or system components where the perspectives are in fact not the same and potentially drastically dissimilar. In this unto common case, the extent to which systems can collaborate on events and information is essentially limited to low-level data-passing with receivers having little or no understanding of content and implication. Simply stated, the problem at the heart of interoperability between symbolic reasoning-based systems resides in the means by which information-centric systems exhibiting wholly, or even partially disparate perspectives, can interoperate at a meaningful and useful level.

The solution to this dilemma can take primarily two different directions. The first of these paths focuses on the development of a *universal* ontology. Such an ontology would represent a single, all inclusive view of the world. Each system would utilize this representation as the core informational basis for operation. Since each system would have knowledge of this common representation of the entities, notions, and concepts, interoperability at the information level would be clear and concise requiring no context-diminishing translation. However, as straightforward as this may appear there are two major flaws with this approach. First, in practicality it is highly unlikely that such a universal description could actually be successfully developed. Considering the amount of forethought and vision this task would require, such an undertaking would be of monumental scale as well as being plagued with misrepresentation. Inevitably, certain notions or concepts would be inappropriately represented in a particular domain in an effort to model them adequately in another.

The second flaw with the universal ontology approach is less obvious but perhaps even more destructive. Considering the number of domains across which such an ontology would need to encompass the resulting ontology would most likely be comprised mainly of generalities. These generalities would typically only partially represent the manner in which any one particular system wished to *see the world*. In other words, due to the number of perspectives a universal ontology would attempt to represent, the resulting ontology would ironically end up being just the opposite, a perspective-absent description falling far short of system needs and expectations. While perspective was the cause of the original interoperability problem it is still a highly valuable characteristic that should not only be preserved but should be wholeheartedly embraced and promoted. As mentioned earlier, perspective is a valuable and useful means of conveying domain-specific notions and bias, which are crucial to information-centric decision-support systems. To omit its presence is to significantly reduce the usefulness of an ontology and therefore the effectiveness of the utilizing decision-support system(s). This coupled with the highly unlikely potential for developing such a comprehensive, inter-domain description of the world renders the universal ontology approach both unrealistic and wholly ineffective.

The second, more promising solution to interoperability between decision-support systems introduces the notion of a *perspective filter*. Based on the fa ade design pattern [1, 2, 3] perspective filters allow core entities, concepts and notion accessible to interoperating systems to be viewed in a more appropriate form relative to each collaborator s perspective. In brief, the fa ade pattern allows for a certain description to be viewed, and consequently interacted with in a more appropriate manner. Similar to a pair of infrared *night vision* goggles, overlaying a filter may enhance or refine otherwise limited information. In the case of ontology-based collaboration this filter essentially superimposes a more perspective-oriented, ontological layer over the initial representation. The filter may not only add or modify the terminology and constraints of the core descriptions but may also extend and enhance it through the incorporation of additional characteristics. These characteristics may take the form of additional attributes and relationships as well as refining constraints. For example, Figure 1 illustrates the use of a logistically oriented perspective filter over a core description of conveyances. Note first that while the core conveyance ontology appears to represent only a limited amount of bias the effectiveness of perspective filters certainly does not require such a general core description. If the core ontology were heavily biased toward a foreign set of perspectives it would simply mean that the perspective filters would need to be more extensive and incorporate additional constraints, extensions, etc. However, for clarity of illustration a limited, rather general core ontology was selected.

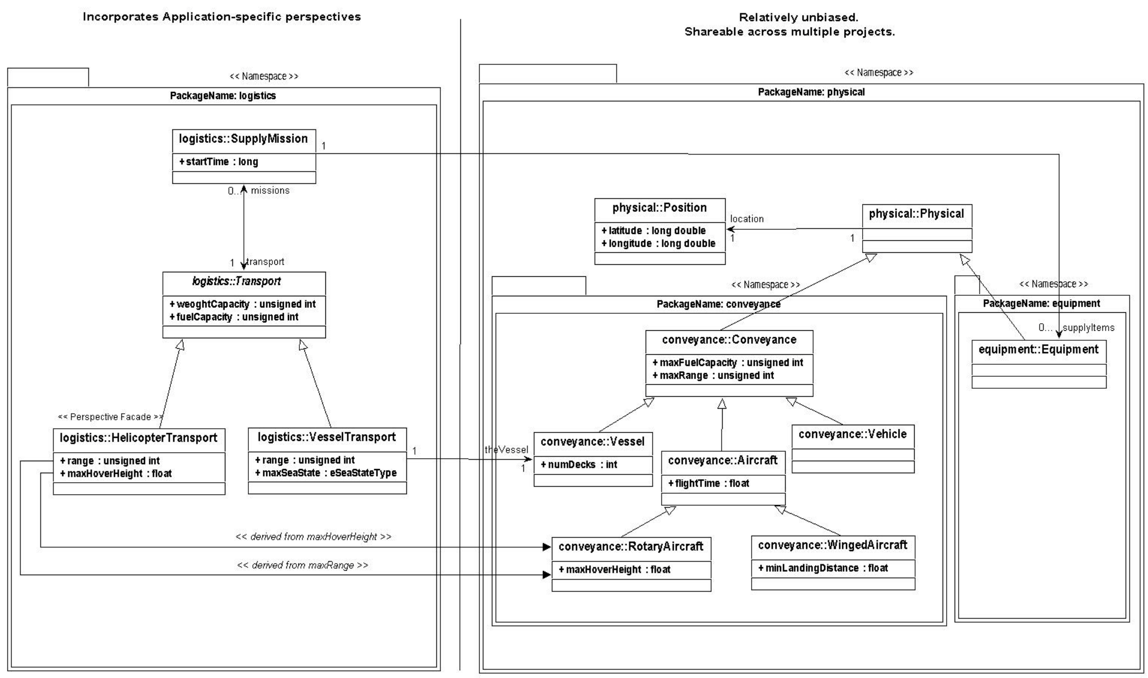

Figure 1 — Partially Derived Logistics Ontology

Core to the logistics perspective presented in Figure 1 is the notion of a transport. However, although the logistics system may have a notion of all of the types of conveyances (i.e., vessels, vehicles, and aircraft) represented in the core ontology it, in the context of this example, may only consider vessels and rotary aircraft as potential transports. In this situation it would be valuable to represent this refined constraint in the ontology forming the representational heart of the logistics system while still employing the core conveyance ontology. As Figure 1 illustrates, representing such refinement can be accomplished by explicitly introducing a constrained notion of a transport in the application-specific filter ontology. An abstract *Transport* is defined to have two specific derivations (*VesselTransport* and *HelicopterTransport*). At this point it is immediately apparent that a vehicle is not a transport candidate. In the context of the example logistics system transports can only be *VesselTransports* or *HelicopterTransports*. The task now becomes linking these two system specific notions to the core conveyance ontology. Relating these two transport types to their conveyance ontology counterparts can be achieved in two different ways. For illustration purposes, the definition of *VesselTransport* adopts the first method while *HelicopterTransport* employs the second. The first method defines an explicit relationship between the *VesselTransport* and the core description of a vessel outlined in the conveyance ontology. Utilizing this approach, obtaining the core information relative to the corresponding *Vessel* from a *VesselTransport* requires both knowledge of their relationship in addition to another level of indirection. For reasons of performance and logical integrity, both of these requirements may not be desirable.

The second method, illustrated in Figure 1 using *HelicopterTransport*, avoids both shortcomings inherent in the first approach. In this case, *HelicopterTransport* exists as a fa ade, or filter, which transparently links at the attribute level into the core *RotaryAircraft* description. That is, each attribute of *RotaryAircraft* desired to be exposed to users of *HelicopterTransport* is explicitly declared in the fa ade. For example, since the maximum range of travel is relevant to the definition of a *HelicopterTransport* the *maxRange* attribute of *RotaryAircraft* (inherited from *Conveyance*) is subsequently exposed in the HelicopterTransport fa ade description. By virtue of being declared in a fa ade any access to such an attribute would be transparently mapped into the corresponding attribute(s) on which it is based. In the case of the *range* attribute of *HelicopterTransport*, access would transparently be directed to the inherited *maxRange* attribute of *RotaryAircraft*. Notice also the use of alternative terminology over that used in the core ontology (i.e., *range* vs. *maxRange*). It should also be noted that the derivative nature of a fa ade attribute is not limited to mapping into another attribute. Rather, the value of a fa ade attribute may also be derived through calculation, perhaps based on the values of multiple attributes residing in potentially several different core objects. In either case, the fact that the value of the fa ade attribute is derived is completely transparent to the fa ade user.

Another perspective-oriented enhancement to the core ontology illustrated in Figure 1 is the notion of a *SupplyMission*. Being a fundamental concept in the example logistics system a supply mission essentially relates supply items in the form of equipment to the transports by which they will be delivered. Once again, the definition of a logistics-specific notion (i.e., supply items) is derived from a notion defined in the core ontology (i.e., equipment). In this case, an explicit relationship is declared linking *SupplyMission* to zero or more *Equipment* items. Since, from the perspective of the logistics system *Equipment* scheduled for delivery are viewed as items that are to be supplied, the term *supplyItems* is used as the referencing nomenclature. Such an enhancement demonstrates the ability to integrate new concepts (i.e., supply missions) with existing core notions.

In the context of interoperability among information-centric, decision-support systems significant benefits could be obtained from essentially drawing relevant concepts and notions into a system s local set of perspective-rich, filter ontologies. As the above example illustrates, key components of these perspective-oriented ontologies could be derived from a set of core, relatively unbiased common notions forming the basis for informational collaboration among systems. There are several benefits to adopting this approach. Collaboration among information-centric, decision-support systems would take place in terms of various core ontologies (i.e., *Conveyance*) with each collaborator viewing these core entities, concepts and notions according to its own perspective. Figure 2 briefly extends the logistics example presented in Figure 1 showing collaboration between the original logistics system and a tactical command and control system. Collaboration between these two example systems is in terms of the common, core ontologies on which they share their derivations. A conveyance is still a conveyance whether it is viewed in the context of logistics or tactical command and control. To represent domain-specific notions (e.g., transport, supply item, tactical asset, etc.) each collaborating system would apply the appropriate filter. Although discussing a conveyance from partially disparate perspectives both systems can collaborate about core entities, concepts , and notions.

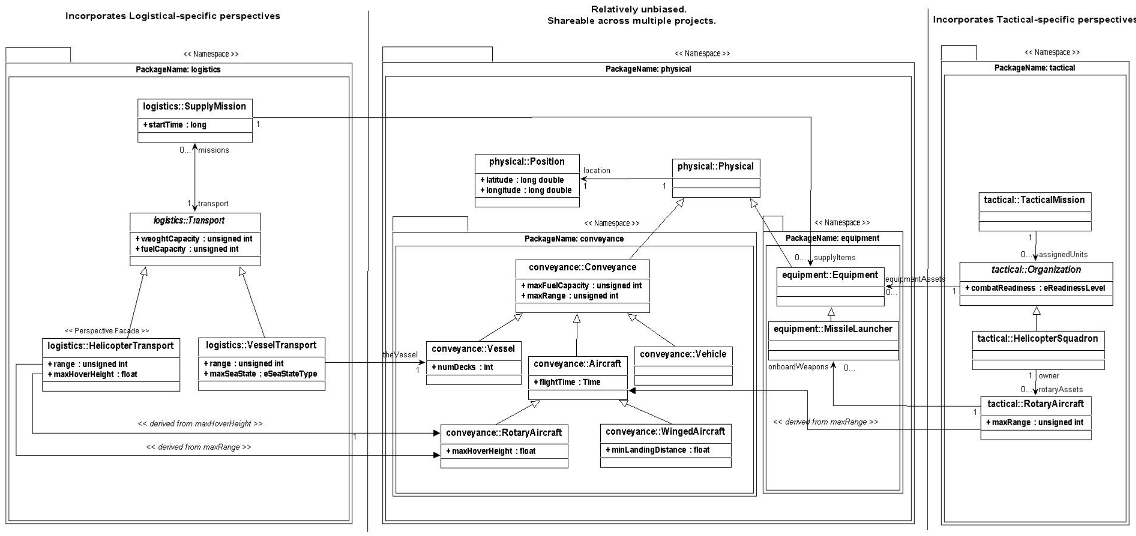

Figure 2 — Two disparate domains linked into the same core ontology

Another advantage of supplementing core, non-system-specific ontologies with perspective rich filters is the preservation of both time and effort during the development of such information-centric systems. Core ontologies could be archived in a sort of ontology library forming a useful reference assisting in the development of new system ontologies. Models created for new decision-support systems could make use of this ontology library as a strong basis for deriving system-specific filters. In addition, such a process would promote the use of common core descriptions increasing the potential for interoperability even further.

Interoperability between disparate decision-support systems is crucial to the operational effectiveness of information-centric, decision-support systems. As the emergence of such systems increases the need to support inter-system collaboration at the information level becomes increasingly critical. By constraining valuable, perspective-based biases to local, system-specific filter ontologies coupled with the use of core, relatively unbiased ontologies, interoperability between disparate information-centric decision-support systems becomes both feasible and effective.

References

[1] Buschmann F, D Schmidt, H Rohnert, and M Stal; "*Pattern-Oriented Software Architecture: A System of Patterns*"; Vol. 2, John Wiley and Sons, New York, New York, 1996.

[2] Buschmann F, R Meunier, H Rohnert, P Sommerlad, and M Stal; "*Pattern-Oriented Software Architecture: A System of Patterns*"; Vol. 1, John Wiley and Sons, New York, New York, 1996.

[3] Fowler M; "*Analysis Patterns: Reusable Object Models*"; Addison-Wesley, Reading, Massachusetts, 1997.

[4] Gomez-Perez, A., N. Juristo and J. Pazos (1995); *'Evaluation and Assessment of Knowledge Sharing Technology'*; in Mars N. (ed.) Towards Very Large Knowledge Bases - Knowledge Building and Knowledge Sharing 1995, IOS Press, Amsterdam (pp.289-296).

[5] Hay D.; "*Data Model Patterns: Conventions of Thought*"; Dorset House, New York, New York, 1996.

[6] Hayes-Roth F, D Waterman and D Lenat (eds.); "*Building Expert Systems*"; Addison-Wesley, Reading, Massachusetts, 1983.

[7] Orfali R, D Harkey and J Edwards; "*The Essential Distributed Objects Survival Guide*"; John Wiley and Sons, Inc., New York, New York, 1996.

[8] Pohl J, A Chapman, K Pohl, J Primrose and A Wozniak; "*Decision-Support Systems: Notions, Prototypes, and In-Use Applications*"; Technical Report, CADRU-11-97, CAD Research Center, Design Institute, College of Architecture and Environmental Design, Cal Poly, San Luis Obispo, CA, January, 1997.

[9] Pohl J; "*Human-Computer Partnership in Decision-Support Systems: Some Design Guidelines*"; in Pohl J (ed.) Advances in Collaborative Design and Decision-Support Systems, focus symposium: International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, August 18-22, 1997 (pp. 71-82).

[10] Tansley D. and C. Hayball (1993); *'Knowledge-Based Systems Analysis and Design: A KAD Developers Handbook* , Prentice Hall.

The Architecture of a Case Based Reasoning Application

Michael A Zang

Senior Software Engineer
CAD Research Center
Cal Poly, San Luis Obispo

Abstract
This paper provides an overview of select architectural concepts, structures, and mechanisms employed in the development of the Collaborative Agent-Based Control and Help System (COACH). COACH is an Office of Naval Research (ONR) sponsored system to demonstrate the feasibility and utility of a software system based on the Integrated Cooperative Decision Model (ICDM Architecture) to facilitate repairs to naval systems by inexperienced personnel. ICDM is a joint product of the CAD Research Center and CDM Technologies. The architectural underpinnings of COACH have subsequently been applied to the development of other ONR projects such as the Ordnance Tracking and Information System (OTIS), and the Shipboard Integrated Logistics System (SILS).

Introduction
During the initial phases of the COACH project three fundamental design concepts were identified that were not well addressed by the technology embodied in ICDM at that time.

1. Probabilistic diagnosis is at the core of most repair problems.
2. It is not practical to hard code rules to deal with every repair situation.
3. Repairmen must be able to interact with the system in a hands free manner.

The case based reasoning paradigm provided solutions to the problems associated with all three concepts. While not a core feature of the paradigm, most implementations support probabilistic notions. A core feature of the paradigm is the capability to add cases over time and the simplistic nature of the underlying knowledge format is ideally suited to end-user or automated extensions to the knowledge base, which in essence enables the enveloping system to learn over time. The question and answer format coupled with the text based similarity mechanisms provided by the paradigm are naturally suited to speech-based interactions with the system.

The remainder of this paper focuses on the ICDM architecture, its underlying concepts, and the extensions incorporated to provide case base reasoning facilities. Additional details on the case based reasoning paradigm are not provided in this paper.

Software Architecture
Since this paper is to deal with architecture it should begin with a definition of the architecture of a software system. Unfortunately there appears to be as many definitions as there are authors in

this field of endeavor. In fact entire web site are devoted to the question what is software architecture (CMU 2001). For example, one definition is The high-level division of a system into major sub-systems and their dependencies (Fowler 239). This definition is fairly non-concise, where is the line drawn between high level and low level, between major subsystem and minor subsystem. Also this definition says nothing about the core mechanisms with which the subsystems collaborate, which is equally important if not more than the dependencies.

Another definition is The set of significant decisions about the organization of a software system (Booch, et al 1999b). The problem with this definition is that what is considered significant is fairly arbitrary. In practice, a significant decision is probably defined as those the system architect got to in the time allocated to produce the system architecture document.

These issues have lead me to define the architecture of a software system as the underlying model from which the system is specified and implemented. Traditionally this model has been resident in the minds of the designers, developers, and project managers associated with the system. With the advent of the Universal Modeling Language (UML) (see Fowler and Scott 1997) and supporting computer aided software engineering (CASE) tools, this model can now be captured in a standard, consistent, and persistent format. Note this model grows and changes over time but at any instant in time it provides the current conception of the system architecture.

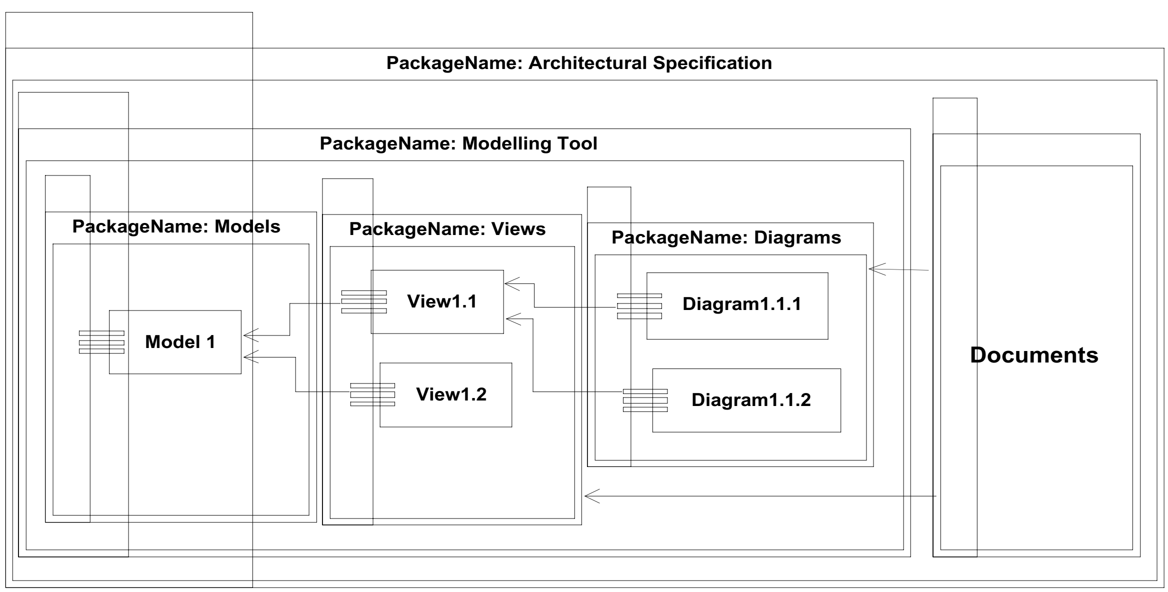

Figure 1 Architectural Specification

One or more models may represent the system architecture. An example of a possible breakdown is the user domain model, system model, and development model. The user domain model is essentially an analysis tool used to understand the user community their responsibilities, organizational structure, existing information system environment. It may also be used to capture the knowledge acquisition process and structure of the resulting artifacts. The system model captures the structure software under development and will be discussed throughout the rest of this paper. The development model captures the development environment and processes as well as the project management aspects of the system such as milestones, deliverables, tasks, and timelines.

While the underlying models represent the system architecture, the architecture is specified through views, diagrams, and documents as depicted in **Figure 1**. One of the particularly powerful aspects of UML is that it is built on an underlying formal grammar. This allows views and diagrams to show specific aspects of the system while contributing to an underlying self-consistent model that is much to complex to depict in any one picture. This approach allows Software Architecture specifications to exist at the multitude of different scopes and levels typically required as shown in **Figure 2**.

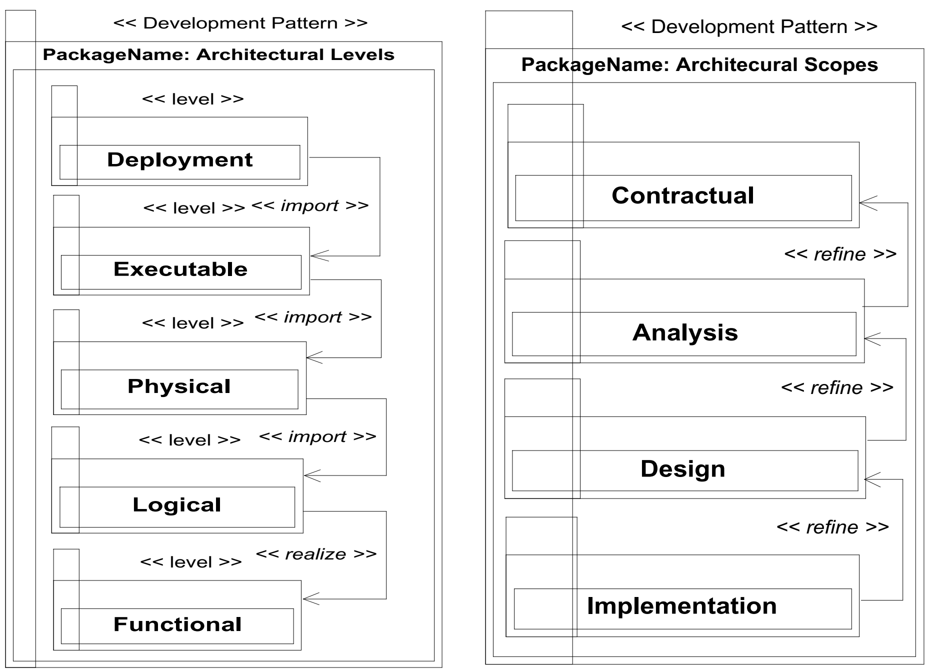

Figure 2 Architectural Scopes and Levels

In addition to UML the architectural approach to these projects extensively utilizes the pattern approach to software engineering. Software Engineering patterns provide the industry with the means to capture proven solutions to software engineering problems in a generic system independent manner. A well-documented pattern provides a unique descriptive name, describes a software engineering problem in regards to a specific context, and presents a well-proven generic scheme for its solution. Patterns in software engineering are most associated with software design due to the classic reference Design Patterns by the gang of four that introduced the industry to the pattern concept (Gamma et al 1994); however, they are equally applicable across the ranges of scale and abstraction within the discipline.

In order for patterns to achieve their primary purpose of capturing expertise for reuse by others they must be organized and catalogued in a pattern system that allows pattern users to quickly find the patterns that address their current issues. In addition to providing an organizational scheme to its constituent patterns, a pattern system should provide a sufficient base of patterns, describe all constituent patterns in a uniform manner, identify relationships between patterns, and show how to apply and implement its constituents.

Common top-level pattern categories are shown in Figure 3. Analysis patterns capture conceptually related domain model entities in a generic fashion that crosses individual domain boundaries providing for the reuse of concepts and allowing for the direct sharing of information between domains. Architectural patterns provide problem solution sets that focus on the system as a whole. Design patterns are similar to architecture patterns except that they provide a lower level focus on the design subsystems rather than the system as a whole. An idiom is low-level programming language specific pattern that describes how to implement particular aspects of a software component or subsystem. An example of a good pattern system is provided in Bushman 1996.

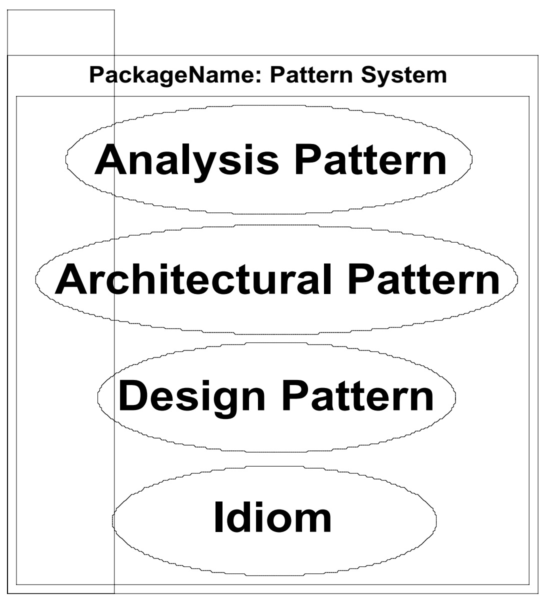

Figure 3 A Pattern System

Patterns are a particularly useful tool for developing and specifying the architecture of a software system. They provide software system architects with the means to quickly identify existing solutions to their architectural problems and provide the architectural design team with a high level descriptive vocabulary with which to discuss design issues. They also capture past experience which guards against major mistakes. This is especially important at the architectural level where a poor choice may not be evident until later on in the development process resulting in costly reworking of the system. They are also very useful in the documentation process as they provide a wealth of information in a very abbreviated format.

Physical Architecture

The physical architecture addresses the runtime aspects if the system. It specifies the system executables and the runtime components from which they are assembled. Runtime components such as dynamic link libraries, Java Jar files, ActiveX controls are built from the source level artifacts specified in the Logical Architecture.

The top level underpinnings of the ICDM architecture are best described by the Blackboard Pattern. This classical architectural pattern has been employed successfully by the artificial intelligence (AI) community since the early 1970 s as an approach to problems for which no deterministic solution strategies are known. The name blackboard was chosen because the approach parallels the situation in which human experts sit in front of a real blackboard and work together to solve a problem (Bushman 1996).

The blackboard architecture employs a collection of independent programs (knowledge sources) that work cooperatively on a common data structure (blackboard). Each program is specialized for solving a particular part of the overall task, and all programs work together on the solution. The specialized programs are completely independent of each other. They do not call each other and there is no predetermined sequence for their activation. The direction taken by the system is primarily determined by the current state of the solution. This type of data directed control facilitates experimentation with different types of algorithms and allows experimentally derived heuristics to control processing.

Prior to the development of COACH a distributed object server and communication facility had been incorporated into ICDM along with a rule-based inference engine and object management layer (OML) for use by end-user client applications. In this arrangement the object server plays the role of the blackboard. The individual agents operating within one or more agent engine instances play the role of knowledge sources. The managers within the agent engine instances provide control over the application of knowledge to the solution being developed by the associated agent federation. The human users, through their client applications, provide an additional source of knowledge and control as depicted in Figure 4.

The incorporation of one or more human users distinguishes this architecture from traditional blackboard implementations that were designed to solve problems for users rather than with them. The partnership between human users and the software agents (knowledge sources) eliminates the control problems often associated with blackboard architectures. Humans can keep the developing solution on track and provide the stimulus to get it going again when stalled. The same data-driven features that provide for the interaction of diverse independent software agents may also be employed to simultaneously link spatially distributed human users into a collaborative environment; thereby realizing an information age version of the conceptual stimulus for which the blackboard pattern is named.

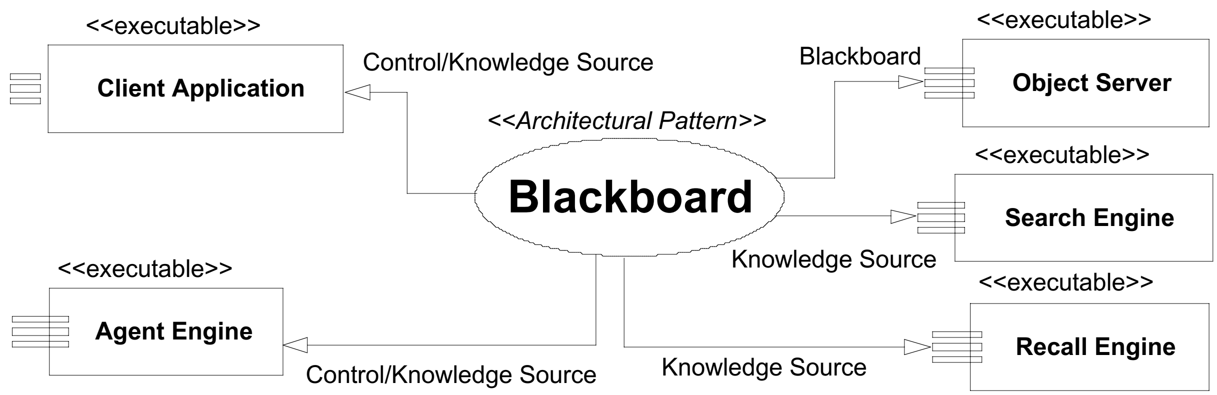

Figure 4 The Physical Architecture

In support of the identified requirements for COACH a case based reasoning facility was incorporated into ICDM in a manner similar to the existing Agent Engine, which prompted the name Recall Engine. Each Recall Engine instance manages multiple recall sessions supported by one or more case bases. Either a human user or a software agent may invoke a recall session. The question and answer dialog used to drive forward the probabilistic values of the retrieved cases associated with the session is posted on the blackboard; thereby, allowing the developing solution to be viewed by all participating knowledge sources. By linking the text based questions to objectified observation concepts and answers to objectified phenomenon human users may respond to the dialog in a natural text based manner while agents may respond with their knowledge in an objectified manner.

This same basic pattern for extending the architecture was repeated to support the OTIS requirement to dynamically plan optimal routes for the movement of ordnance aboard Navy carriers. The Search Engine provides a generic graph searching facility. Each Search Engine instance can manage multiple graphs whose arc weights are dynamically calculated through links to objectified entities within a domain specific instance model, which may in turned be queried by both agents and users for the results of specific searches of various types.

ICDM Subsystems

ICDM utilizes a combination of templated subsystems and code generation to provide high-level domain specific functionality in a generic fashion. This approach greatly decreases the development time of any particular system while ensuring robust performance. The approach utilizes high—level specification formats, such as UML, wherever possible to define the domain specific ontology and logic of a system. Code generators are then employed to translate the high-level specifications to the low-level targets specified in the subsystem templates. Subsystems may be precompiled much like a commercial database system in which case the templated entities are loaded at runtime to tailor it to the domain. This is the approach used by the Agent, Recall, and Search Engines. Alternatively the code generators may produce entities that are compiled into the subsystem as is done with the Object Server. In addition to providing the templated entities, some subsystems may require certain base level entities in the domain specific ontology like the observation and action packages required by the Recall Engine. The subsystems also require the means to communicate in a distributed fashion. This capability is provided by the CORBA implementation of the Object Broker Pattern (Bushmann et al 2000). These ideas are captured in Figure 5.

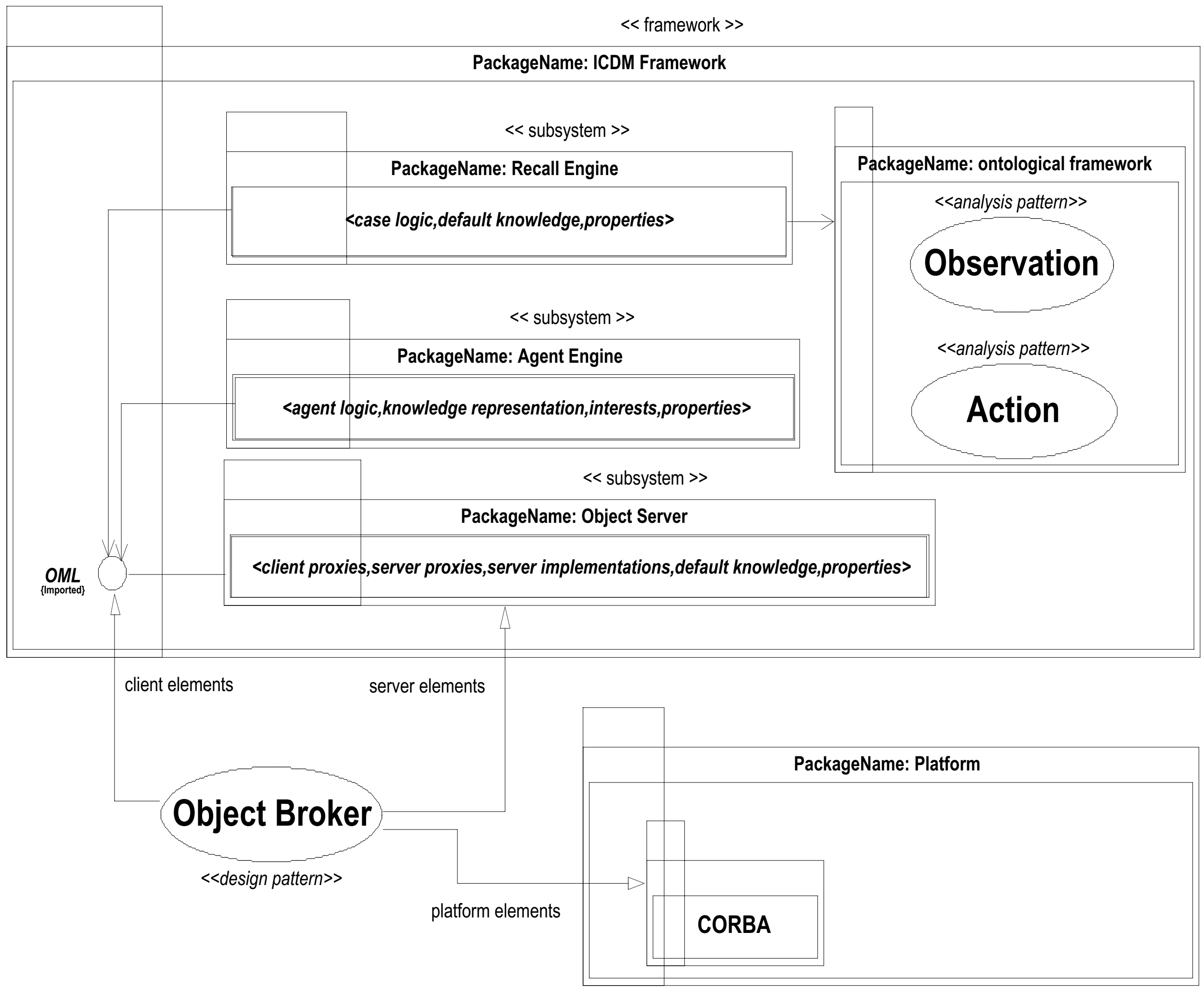

Figure 5 ICDM Subsystems

Logical Architecture

The logical architecture specifies the source and compile-time artifacts from which the physical architecture is built. The top-level local design addresses the need to share system components across families of similar systems and to specifically identify and capture the core technology of the company independent of any particular project. It partitions the design artifacts into four interdependent relaxed layers as depicted in
Figure 6. The unique aspects of a specific system design are grouped into the ICDM system layer. The artifacts contained in this layer leverage heavily on the subsystems and service libraries provided by the underlying ICDM Framework layer and must be considered in relation to the framework to be fully understood.

The general design artifacts applicable to a wide-range of decision support systems have been abstracted from existing systems over the years into the ICDM framework, ICDM toolkit, and ICDM guidelines, which are representative of the research center s core technology. The toolkit provides the development and build environment including the code generators, which transform ICDM System layer artifacts into subsystem targets specified in the ICDM Framework layer. The ICDM guidelines provide informal descriptions of the ideal characteristics of a good decision support system and capture the vision of the center s directors, which serve as a backdrop against which system design decisions are evaluated.

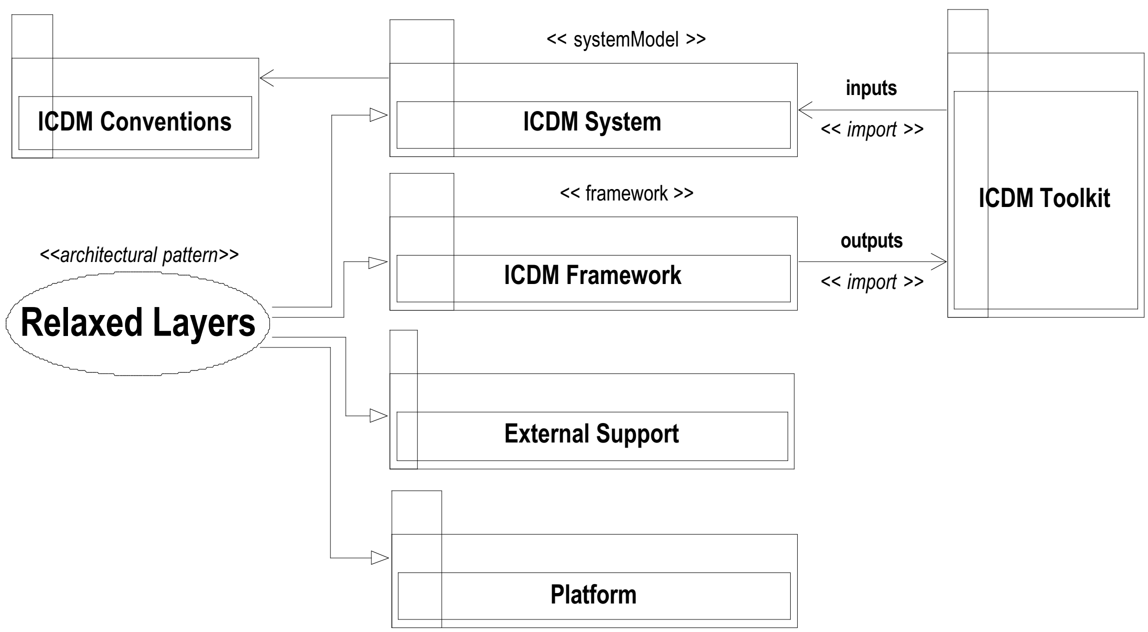

Figure 6 Top-level System Design

The Relaxed Layers pattern (Buschmann 1996) indicates the call level dependencies between the ICDM System layer and the ICDM Framework layer may only be in the direction from system to framework. The framework contains many high level subsystems that are indirectly dependent on the system layer to provide domain specific context. The subsystems work with these elements at the meta-level and therefore do not violate the call-level dependencies. These elements are often specified in a high-level form, such as UML, that is abstracted from any particular implementation.

The External Support and Platform layers group the externally developed elements of the system. It is important to differentiate external design elements at the architectural level because they are relatively fixed and may limit the flexibility of the system to evolve over time. They may also have associated runtime issues such as licensing fees and runtime validation problems. The Platform layer is distinguishable from the External Support Layer in that it groups the relevant external elements provided by the computing infrastructure of the client enterprise. These elements need to be distinguished from other external elements because their configurations and upgrades are outside the control of the system s developing organization.

System Tiers

The system specific design is further structured into three distinct tiers as described by the Information System pattern (Fowler 1997) as depicted in Figure 7. The Domain Tier provides a direct executable model of the system domain that is independent of any particular application or source data model. It represents the active core of the system and provides the central focus for the development effort. The Application Tier provides local applications to support domain interactions of specific user groups. The Data Tier provides for the persistent storage of the data that underlies the information represented by the domain model.

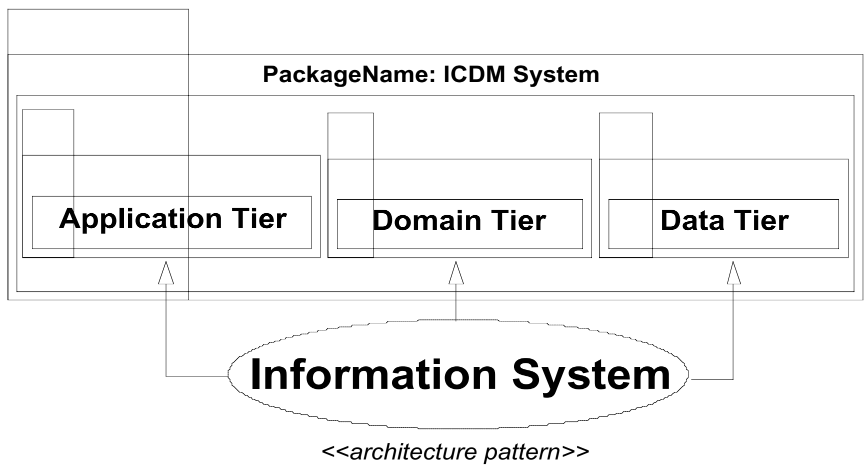

Figure 7 ICDM System Layer Structure

The Information System pattern was selected to address the fundamental decision support system requirements to provide concurrent collaborative support to multiple users, to provide a high-level objective model of the domain that provides the necessary context to support agent-based reasoning, and to interoperate with existing data based systems within the system domain.

Domain Tier

The core of this architecture is the Domain Tier. The Information System pattern assigns the responsibility of saving/restoring the associated domain model to/from the Data Tier to the Domain Tier. This responsibility is typically addressed by providing the individual domain model objects with the capability to save and restore themselves, which is reasonable for simple stand-alone systems that have the complete freedom to specify the storage format of their persisted elements. Unfortunately, real-world systems are rarely this simple, especially those geared toward decision support. Decision support systems must interact with existing systems, taking feeds as necessary, and dealing with the fact that many systems with varying representations (ie. relational, hierarchical, flat files, etc.) may have to be accessed to get the integrated picture required to provide adequate decision support.

The code required to implement this type of external system interaction is substantial and will pollute the purity of the domain model masking its initial intent and limiting its utility in other contexts. This dilemma is addressed by partitioning these responsibilities of the Domain Tier between a Data Interface Tier and a Representation Tier as shown in Figure 8. The Domain Tier Representation provides the executable model of the domain, while the Domain Tier Data Interface assumes the responsibility for moving information between the Representation and Data Tier. This level of indirection also provides the system with the additional flexibility required to more easily adapt to Data Tier changes over time or due to local variations at different deployment locations. The Data Broker pattern (Fowler 1997) describes the internal structure and dynamic behavior of the Data Interface.

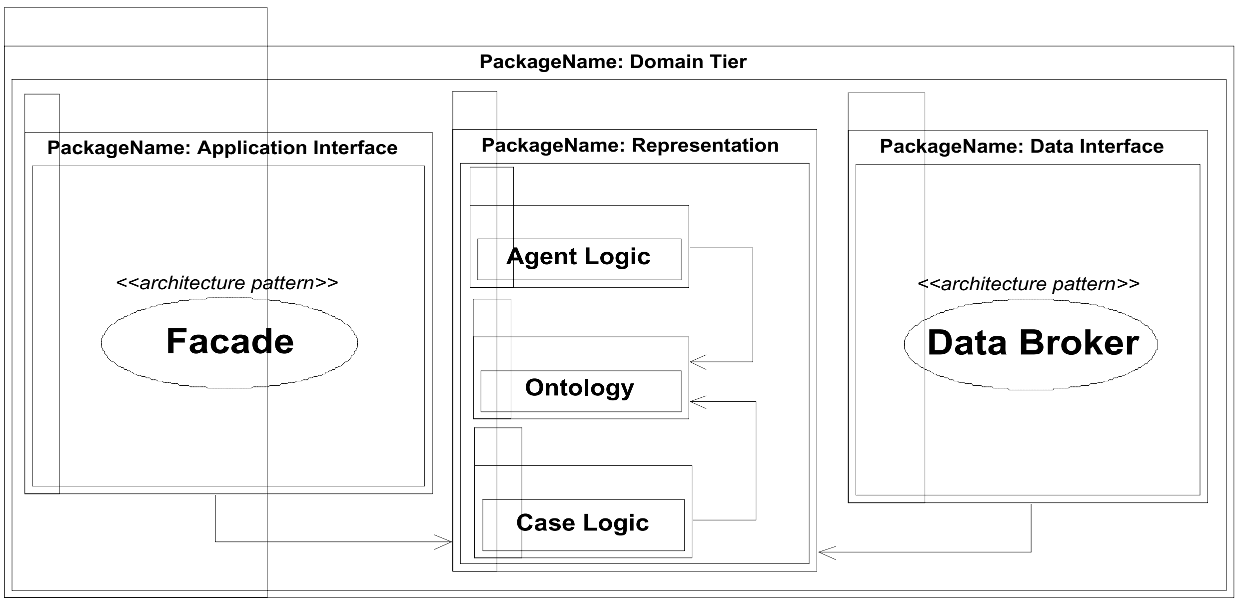

Figure 8 The Domain Tier

The Domain Tier must also provide an interface for the various applications within the domain. The pure representational model is not ideally suited for this purpose due to the complex interrelationships and high-level domain specific type specifications. It also does not address the transactional nature of the interactions between the user applications and the domain. In order to address these deficiencies an additional fa ade (Fowler 1997) based sub tier tailored to the needs of the system s applications is inserted into the Domain Tier. This application interface is responsible for all accesses to the domain representation and does any processing other than that specifically required for the user interface. The addition of this layer also benefits the development process as it allows user interface and domain model design to occur in parallel somewhat independent of one another. Once these pieces stabilize facades are developed that map the interface into the domain.

Within the context of this architecture, an information system utilizes a class based object model to represent the domain. Classes represent the types of things within the domain and are structured into a hierarchy that relates similar things. They serve as templates for the creation of objects that specify object characteristics in terms of attributes, object behavior in terms of operations, and object context in terms of associations. A decision support system can be thought of as a value added extension to a traditional information system. Within the context of a decision support system, the information system object model is known as the ontology. The ontology provides the domain vocabulary upon which the agent logic is specified in the form of expert system rules. This logic is used to express the business rules of the domain, maintain high-level derived information, and to generate alerts and statements of implication.

From the developer perspective, the rule-based representation of the agent logic is very flexible in dealing with dynamic change; however, since the rules are compile time entities they do not provide this same flexibility to system users at runtime. This is where the case logic is particularly useful. The case logic uses a fixed compile time model composed of problems, questions, actions, and their interrelationships. The domain specific nature of the case logic is therefore represented in the form of object instances rather than model classes. This allows the case logic to be dynamically extended or modified at runtime either directly or indirectly (through embedded system learning processes) by system users. The case logic is also expressed in a form that serves as an appropriate basis for English based, interactive dialogs between the system and the system users to zero in on appropriate courses of action.

Summary

The continued evolution of the ICDM architecture to address system specific requirements has greatly enhanced development productivity and the quality of the client systems. The trend towards high-level model based (UML) specification for domain specific elements coupled with code generation to framework level targets is expected to continue. The capabilities of the Recall and Search engines continue to progress and the incorporation of other AI based domain facilities such as neural networks and probabilistic engines based on Bayes law are expected in the future.

References

Booch, Grady and Ivar Jacobson and James Rumbaugh (1999); The Unified Modeling Language User Guide; Addison Wesley

Booch, Grady and Ivar Jacobson and James Rumbaugh (1999); The Unified Software Development Process; Addison Wesley

Buschmann, Frank and Regine Meunier and Hans Rohnert and Peter Sommerlad and Michael Stal (1996); Pattern-Oriented Software Architecture Volume 1, A System of Patterns; John Wiley and Sons

Buschmann, Frank and Hans Rohnert and Douglas Schmidt and Michael Stal (2000); Pattern-Oriented Software Architecture Volume 2, Patterns for Concurrent and Networked Objects; John Wiley and Sons

CMU (2001); How Do You Define Software Architecture; Carnegie Mellon Software Engineering Institute; http://www.sei.cmu.edu/architecture/definitions.html

Kleppe, Anneke and Jos Warmer (1999); The Object Constraint Language, Precise Modeling With UML; Addison Wesley

Fowler, Martin (1997); Analysis Patterns, Reusable Object Models; Addison Wesley Longman

Fowler, Martin and Kendall Scott (1997); UML Distilled, Applying the Standard Object Modeling Language; Addison Wesley Longman

Gamma, Erich and Richard Helm and Ralph Johnson and John Vlissides (1994); Design Patterns, Elements of Reusable Object-Oriented Software; Addison Wesley

Hay, David C. (1996); Data Model Patterns, Conventions of Thought; Dorset House

Mowbray, T. and W. Ruh (1997); Inside CORBA, Distributed Object Standards and Applications; Addison Wesley Longman

Pohl J (1997); Human Computer Partnership in Decision-Support Systems: Some Design Guidelines; in Pohl J (ed.) Advances in Collaborative Design and Decision-Support Systems, focus symposium: International Conference on Systems Research, Informatics and Cybernetics, Baden-Baden, Germany, August 18-22, 1997

Pohl J, and A Chapman and K Pohl and J Primrose and A Wozniak (1997); Decision Support Systems: Notions, Prototypes, and In-use Applications; Technical Report, CADRU-11-97, CAD Research Center, Design Institute, College of Architecture and Environmental Design, Cal Poly, San Luis Obispo, CA, January, 1997

Multi-Viewpoint-Clustering Analysis (MVP-CA) Technology for Analysis of Integrated Marine Multi-Agent Command and Control System (IMMACCS)

Mala Mehrotra & Dmitri Bobrovnikoff
***Pragati Synergetic Research, Inc., Cupertino CA*.**

Abstract. We present the results obtained by analyzing several IMMACCS agents with Pragati's Multi-ViewPoint-Clustering Analysis (MVP-CA) tool. Key findings include: exposure of existing software architecture, generation of intermediate concept nodes to aid in user comprehension of the knowledge base, and detection of templatizable regions which could make the system more reusable and interoperable. Pragati's Multi-ViewPoint-Clustering Analysis (MVP-CA) tool provides a support framework for analyzing large knowledge-based systems from multiple perspectives through clustering. It is a semi-automated tool that allows the user to focus attention on different aspects of the problem domain and thus provides a valuable aid for comprehension, maintenance, interoperability, integration and evolution of large and complex knowledge-based systems. MVP-CA generates usage-based knowledge trees by reverse engineering a knowledge base in a user-directed fashion. Often, the actual usage patterns are found to contrast in interesting ways with pre-declared class hierarchies such as the IMMACCS object model. The application of the MVP-CA tool provides a high-level functional view of the base ontology and the rules that use it. It augments the information-centric base ontology with a knowledge-centric view by extracting clusters of rules having a functional basis or role in the system.

1. Motivation

The IMMACCS (Integrated Marine Multi-Agent Command and Control System) system, developed by CAD Research Center, provides near real-time decision support for military command and control personnel in the form of enhanced situation awareness. It is an adaptive system that uses agents to filter and tag information according to its currency, relevance and reliability. IMMACCS works collaboratively, with the computer-based agents helping human users to solve the problem at hand. In order to be responsive to human intent, the system has been designed to process information, not just data. It accomplishes this goal by maintaining a global IMMACCS Object Model that allows it to access objects in terms of their behavioral characteristics and relationships to other objects. An agent engine is responsible for the environment's dynamic problem-solving aspects. It generates the desired views of the battle space to support the planning and training activities. The informational aspects of the objects are thus separated from the logic aspects of the system.

The bulk of the effort in building such multi-agent systems has thus been devoted to attempting to define the information nuggets or objects at a high-enough conceptual level. Such an ontology needs to capture the belief system for each agent so that the problem to be solved can be formulated in concrete as well as natural terms. In other words, the aim is to capture the real-world problem environment in terms of all objects of interest in the environment, their behavioral characteristics, and their interrelationships, such that the problem solving aspects of the agents can be simplified. Agent reasoning and collaboration can then take place in the context of such an ontology through formulation of simplified agent rules.

Even though every effort needs to be taken to define the right information at the right conceptual level in the ontology, it is often the case that all the different aspects of object and problem definition cannot be foreseen a priori in the forward engineering phase of the project. Often certain subtle but important relationships become evident through time, after studying the patterns of data/information accesses in the system. In this project, we have shown the feasibility of detecting such patterns in the knowledge base through Pragati's MVP-CA (Multi-ViewPoint Clustering Analaysis) technology, so as to expose the system in the context of **how the various concepts are used** in the knowledge base, as opposed to **how they are declared.** By advocating such a reverse engineering approach,we provide a complementary perspective on the relationships of the concepts. The clusters provide us with a functional perspective on the *degree* to which concepts are inter-related in the system. Also if there are gaps across the declared concepts, then formation of intermediate level concepts is suggested by the system. Therefore, the advantage in reverse engineering these systems is that the knowledge being exposed has a functional basis, that is, one is conscious of how it is being used, as opposed to how they were declared. Hence, new connections across concepts can be created and defined contextually.

In our experience with the IMMACCS system, we have discovered that even though the rules in the agents are well-organized in their respective groups, each rule is rather long, containing a lot of repeated clauses across the rules. Since each rule references many different types of objects from the object model, the knowledge base becomes very opaque from an understandability point of view; one has to frequently switch contexts in order to understand each rule. Often, a set of rules display only slight variations on a base concept. This implies either a need for additional structure in the object model to accommodate the variations, or else a need to factor the commonalities into higher-level rules. Such changes would serve to make the rule base more efficient and comprehensible. The strong similarity across groups of rules can also be exploited to formulate rule templates that would facilitate

- identification of interoperable/reusable components in the system
- new knowledge acquisition and
- long-term maintenance of the rules

In this paper we discuss our experiences of applying Pragati's Multi-ViewPoint-Clustering Analysis (MVP-CA) prototype tool to expose such conceptual modules in a system, by performing a combination of statistical and semantic clustering on the rules in the system. These clusters can provide a foundation for building intermediate concept nodes in the knowledge base as they expose groups of rules in the context of their usage. As an alternative to the declared class-subclass hierarchy in the IMMACCS object model, MVP-CA tool semi-automatically generates a complementary knowledge tree by reverse engineering the knowledge base. Thus the application of the MVP-CA tool is shown to provide an even higher-level view of the base ontology, that is, augment the base ontology which is information-centric with even higher-level abstractions which promises to make the system knowledge-centric.

2. Multi-ViewPoint Cluster Analysis (MVP-CA) Technology

Overview of the MVP-CA Tool

Pragati's Multi-ViewPoint-Clustering Analysis (MVP-CA) tool provides a framework for clustering large, homogeneous knowledge-based systems from multiple perspectives. It is a semi-automated tool allowing the user to focus attention on different aspects of the problem, thus providing a valuable aid for comprehension, maintenance, integration and evolution of knowledge-based systems (Mehrotra 1994, Mehrotra 1995b, Mehrotra 1996). The generation of clusters to capture significant concepts in the domain seems more feasible in knowledge-based systems than in procedural software as the control aspects are abstracted away in the inference engine. It is our contention that the MVP-CA tool can form a valuable aid in exposing the conceptual software structures in such systems, so that various software engineering efforts can be carried out meaningfully, instead of in a brute-force or ad-hoc manner. In addition, insight can be obtained for better reengineering of the software, to achieve run-time efficiency as well as reduce long-term maintenance costs. It is our intention to provide a comprehension aid base first, through our MVP-CA tool, for supporting all these software engineering activities (Mehrotra 1999).

The MVP-CA tool consists of two major stages: Cluster Generation and Cluster Analysis. In the Cluster Generation phase the focus is on generating meaningful clusters through clustering analysis techniques augmented with semantics-based measures. The clustering algorithm starts with each rule as a cluster. At each step of the algorithm, two clusters which are the most "similar" are merged together to form a new cluster. This pattern of merging forms a hierarchy of clusters from the single-member rule clusters to a cluster containing all the rules. The "similarity" of rules is defined by a set of heuristic distance metrics which measure the relatedness of two rules in a rule base. The type of information captured by the metrics is to some degree dependent on the class of the expert system being analyzed (Chandra 1986, Mehrotra and Wild 1995, Mehrotra 1995). By utilizing different distance metrics and parameters for those metrics, individual clustering runs are generated. Once clusters have been found, the Cluster Analysis Phase can proceed. In this phase, the user is aided by a set of detection routines that flag potentially interesting clusters. Parent clusters and child clusters help the user in either breaking up a high level concept into constituent concepts or combining lower level concepts into higher-level abstract concepts. Often the formation of higher-level concepts is reflected in the topology of the mergings, which can be visualized through dendograms presented by the tool. This then points to the groups that need to be examined more closely. The clustering and analysis process is iterative; results from one clustering run will often suggest a new set of parameters for a subsequent run.

Overview of IMMACCS

The FIRES agent is one of thirteen agents that have been built in IMMACCS. Some of the other agents are: Sentinel, Rules of Engagement (ROE), Engagements, Logistics, Hazard, Intelligence, Decision Point, Blue-On-Blue Agent. The FIRES agent responds to "Call for Fire" messages in the system. In response to such a message its purpose is to select the best weapon based on availability, deliverability and acceptability. To accomplish this goal it accesses concepts such as range, time of flight, target type, urgency, circular error of probability (CEP), effective casualty rate (ECR), availability and rules of engagement (ROE) from the IMMACCS object model. The deconfliction rules in the FIRES agent also address the trajectory of the munitions relative to the position of other friendly assets and infra structure objects. The FIRES agent contains 49 COOL rules and is the largest knowledge base compared to the other thirteen in IMMACCS. The total number of rules across all agent rules in IMMACCS is 153.

3. Experimental Results

Multiple runs were performed with different parameter settings for the FIRES agent data set. In this section we discuss the results of those clustering runs.. We first describe the high-level software architecture and then present the three broad categories of concepts that were discovered, *Conflicts, Targeting and Weapons*. We can generalize the qualitative aspects of our results by stating that the clusterings helped us discover the following:

- *High-level software architecture*
  - To aid comprehension of the knowledge base by helping us extract the "big" picture
- *Opportunities for insertion of intermediate concept nodes in the object model*
  - To aid more efficient knowledge organization (static ontological engineering aspect) and
  - To aid with search and retrieval of concept terms (dynamic aspect)
- *Opportunities for template formation (structurally common axioms) in both intra- and inter-agent analysis*
  - To aid detection of interoperable rule sets having a functional basis
  - To aid more efficient knowledge entry

3.1 IMMACCS FIRES Agent's Software Architecture

Figure 1 provides a high-level view of the FIRES agent's software architecture, as extracted using the MVP-CA clustering tool. Concepts have been identified at two levels. On the top-level we have discovered three main or broad categories of problem-solving concepts. We have called these the Weapons, Targeting and Conflicts group. The names for these groups have been coined in an attempt to categorize the various observation subgroups that were found to exist under the broad concept. In other words these groups consist of other subgroups feeding into the umbrella concept consisting of Weapons, Targeting or Conflicts.

The subgroups that were found to exist under the Weapons group deal with either weapon capabilities or guided munitions or concentrate on various aspects of Weapon Presentation. The Weapon Presentation group further subdivides into the Weapon Selection and Weapon Recommendation groups. The Conflicts cluster had two parallel sets of rules that dealt with the concept of a weapon trajectory conflict due to a building or a rotary wing being in the way. The concept of Targeting yielded two major subgroups that utilize disjoint concepts of non-enemy entity near target and target range for the solution process. The discussions that follow will be in the context of these subgroups that were identified through the tool.

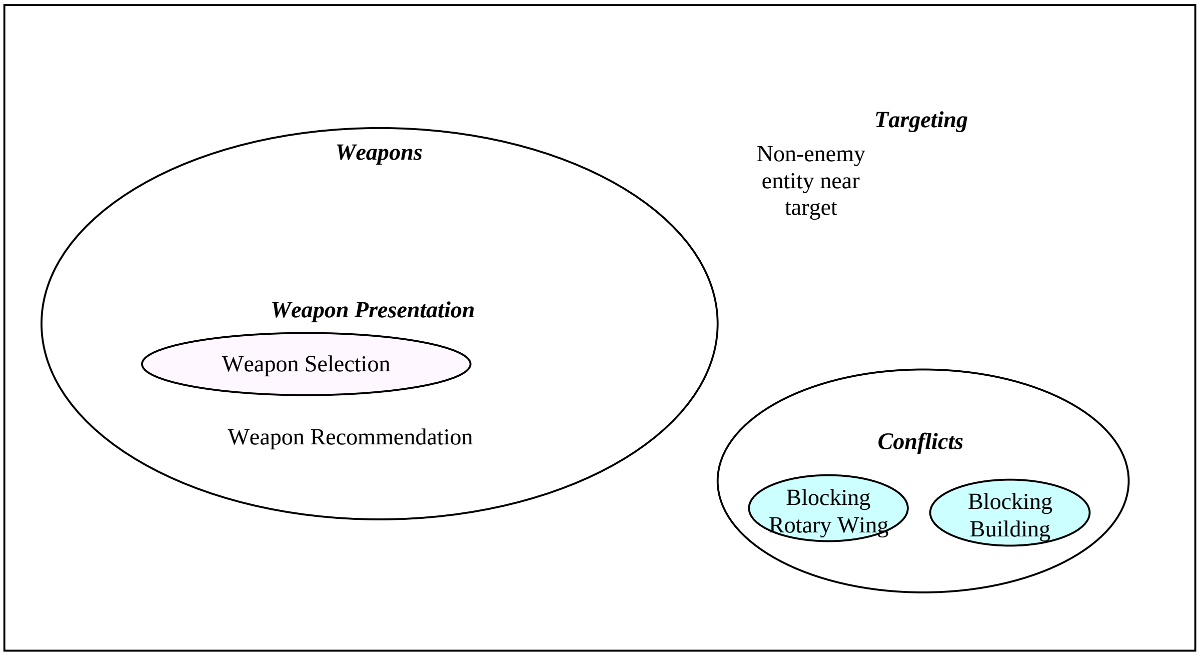

Figure 1: IMMACCS FIRES Agent's Software Architecture (Extracted via MVP-CA)

3.2 Intermediate Concept Formation

Intermediate concept node formation is geared towards augmenting the system's object model or ontology from a functional perspective. All the relationships in the object model are declared in the forward engineering phase of system development. Reverse engineering the system through clustering provides a "hind-sight" benefit in evaluating those relationships in the context of their usage. In other words, if a certain combination of concepts proves handy for providing a particular functionality, perhaps a composite concept addressing that functional aspect needs to be in place in the object model as an abbreviation or shorthand reflecting the reuse of the combination. Intermediate concept node formation is very akin to common factoring in compiler design where the code that is used repeatedly can be factored out and compiled in an optimized manner for run-time efficiency. It allows the user to formulate his/her ideas in terms of composite concepts so that, once a base rule captures the essence of the functionality in the common set, only the unique portions need to be mentioned in the new rules. We have mentioned in our preamble that each rule in IMMACCS is so long that the meaning is not immediately clear from a manual examination of the rule base. Clustering the rules in IMMACCS showed that repeated references were being made to the same objects in the object model, with only very minor variations across a rule set. Intermediate concept node formation attempts to abstract the commonalities across the objects in a rule cluster, so that the future rule formulations are simplified conceptually.

Thus, in order to reduce the opaqueness of the rules we have proposed the following solution for restructuring the rule base through the formation of intermediate concept nodes:

1. Identify clusters of rules with similar content.
2. Create an intermediate object to capture functional aspects of the rule cluster.
3. Formulate a base rule with the intermediate object to capture the commonalities.
4. Adapt original rules as a derivation from base rule and instantiation of the intermediate object.

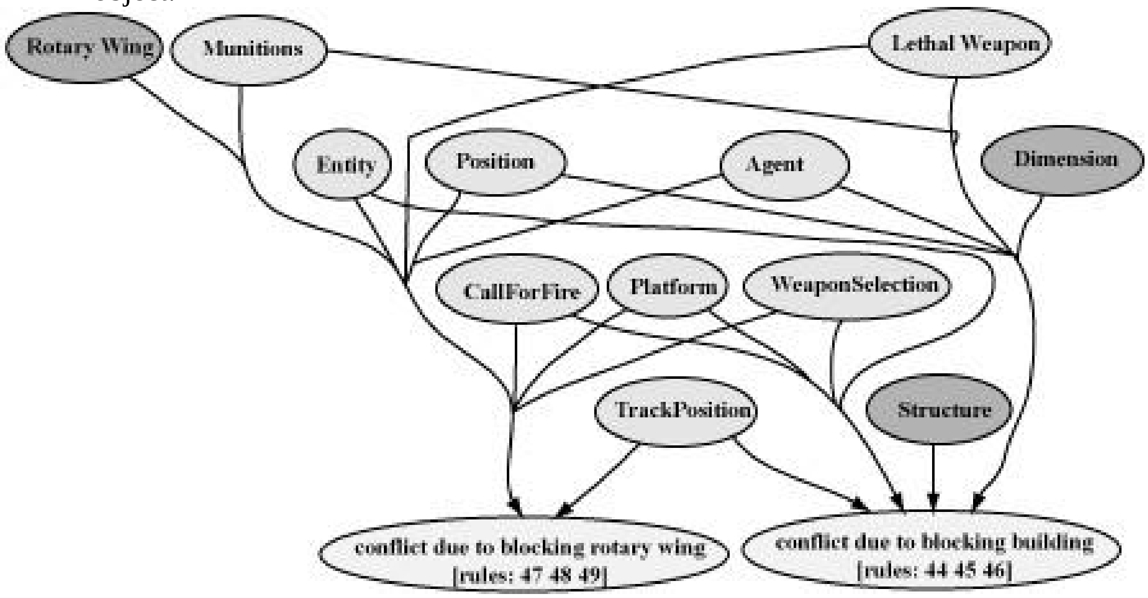

Figure 2: Term Usage for Conflicts Cluster

Consider for example, the Conflicts cluster represented in Figure 2. It contains two subclusters*: conflicts due to blocking rotary wing* and *conflicts due to blocking building*. The figure shows the objects from the IMMACCS object model, such as Munitions, Entity, Position, etc. that are referenced by the rules in the cluster. Notice however, that the Rotary Wing is exclusive to one sub cluster and so is Structure and Dimension, because the arc from these nodes lead to only their respective sub clusters. Figure 2, and others that follow, represent visually **how intermingled the various object nodes are with respect to the problem formulation**. The cluster consists of the following rules:

```
Rule # 44   FIRES::Structure_Trajectory_Weapon
Rule # 45   FIRES::Structure_Trajectory_Entity
Rule # 46   FIRES::Structure_Trajectory_Platform
Rule # 47   FIRES::RotaryWing_Trajectory_Weapon
Rule # 48   FIRES::RotaryWing_Trajectory_Entity
Rule # 49   FIRES::RotaryWing_Trajectory_Platform
```

Rules for Conflicts Cluster

We present the **Structure_Trajectory_Weapon** rule from the FIRES agent in Program Segment 1 to show its complexity. This rule fires if a building is blocking the trajectory of a weapon. While not detailed here, the other rules in the *conflicts due to blocking rotary wing* cluster,

```
(defrule FIRES::Structure_Trajectory_Weapon
(declare (salience -5))
(object (is-a Agent)(name ?oFireAgent)(agentId "FIRES"))
(object (is-a CallForFire)(name ?oCFF)(targetLocation ?oTargetPos))
(object (is-a Position)(name ?oTargetPos)(latitude ?fTLAT)
            (longitude ?fTLONG)(altitude ?fTa))
(object (is-a WeaponSelection)(name ?oWS)(CFFId ?oCFF)
            (cons $?lCONS)(pros $?lPROS)(choice FEASIBLE)(ammoType AMMO)
            (rating ?nRATING)(ammoId ?oMN)(weaponId ?oLW)(entityId ?oET))
(test (member$ "within range" $?lPROS))
(object (is-a Munitions)(name ?oMN)(maxSpeed ?V))
(object (is-a LethalWeapon)(name ?oLW)(encyclopedic FALSE)
            (weaponAmmo ?oMN)(location ?WLoc))
(object (is-a TrackPosition)(name ?oWLoc)(latitude ?fENTLAT)
            (longitude ?fENTLONG)(altitude ?fSa))
(test (<> ?fENTLAT ?fENTLONG 0))
(object (is-a Structure)(referenceName ?building)
            (location ?oBuildingPos)(structureDimension ?oDimen))
(object (is-a Dimension)(name ?oDimen)(height ?fheight))
(object (is-a Position)(name ?oBuildingPos&~?oTargetPos)
            (latitude ?fBLAT)(longitude ?fBLONG)(altitude ?fBa))
(test (InTheWay ?fENTLAT ?fENTLONG ?fBLAT ?fBLONG ?fTLAT ?fTLONG))
(test (not (member$ (str-cat ?building
            ", potential obstacle in trajectory path") $?lCONS )))
(test (> 0 (TrajectoryCheck ?fENTLAT ?fENTLONG ?fSa ?fBLAT ?fBLONG
            (+ ?fBa ?fheight) ?fTLAT ?fTLONG ?fTa ?V)))
=>
(bind ?delta (TrajectoryCheck ?fENTLAT ?fENTLONG ?fSa ?fBLAT ?fBLONG
            (+ ?fBa ?fheight) ?fTLAT ?fTLONG ?fTa ?V))
(send ?oWS put-rating (+ ?nRATING (* 10 ?delta)))
(send ?oWS put-cons (insert$ $?lCONS 1 (create$ (str-cat ?building
            ", potential obstacle in trajectory path")))))
```

Program Segment 1: *Original "Structure_Trajectory_Weapon" Rule*

Structure_Trajectory_Entity and **Structure_Trajectory_Platform,** are very similar to **Structure_Trajectory_Weapon**.

Upon examination of rules 44, 45, and 46, we find that it is possible to factor out the rules' shared object usage by introducing an intermediate concept node, *ConflictDueToBlockingBuilding*, as shown in Program Segment 2.

```
(make-instance of ConflictDueToBlockingBuilding
      ; building-related slots
      (buildingName ?building) (buildingLatitude ?fBLAT)
      (buildingLongitude ?fBLONG) (buildingAltitude ?fBa)
      (buildingHeight ?fheight)
      ; target-related slots
      (targetLatitude ?fTLAT) (targetLongitude ?fTLONG)
      (targetAltitude ?fTa)
      ; munition-related slots
      (munitionMaxSpeed ?V)
      ; weapon selection-related slots
      (weaponSelection ?oWS) (weaponId ?oLW) (ammoId ?oMN)
      (weaponRating ?nRATING) (weaponCons ?lCONS))
```

Program Segment 2*: Intermediate Concept Node* *"ConflictDueToBlockingBuilding"*

We also introduce a new base rule, *Structure_Trajectory*, that abstracts the rules' common functionality. This base rule appears in Program Segment 3.

```
(defrule FIRES::Structure_Trajectory
(declare (salience -5))
(object (is-a Agent) (name ?oFireAgent)(agentId "FIRES"))
(object (is-a CallForFire) (name ?oCFF)
            (targetLocation ?oTargetPos))
(object (is-a Position) (name ?oTargetPos) (latitude ?fTLAT)
            (longitude ?fTLONG) (altitude ?fTa))
(object (is-a WeaponSelection)(name ?oWS) (CFFId ?oCFF)
            (cons $?lCONS)(pros $?lPROS) (choice FEASIBLE)
            (ammoType AMMO) (rating ?nRATING)(ammoId ?oMN)
            (weaponId ?oLW))
(test (member$ "within range" $?lPROS))
(object (is-a Munitions) (name ?oMN) (maxSpeed ?V))
(object (is-a Structure) (referenceName ?building)
            (location ?oBuildingPos) (structureDimension ?oDimen))
(object (is-a Dimension) (name ?oDimen) (height ?fheight))
(object (is-a Position) (name ?oBuildingPos&~?oTargetPos)
            (latitude ?fBLAT) (longitude ?fBLONG) (altitude ?fBa))
(test (not (member$ (str-cat ?building
            ", potential obstacle in trajectory path") $?lCONS )))
=>
; create intermediate object
(make-instance of ConflictDueToBlockingBuilding
... [see above for full intermediate object definition]))
```

Program Segment 3: *New Rule Structure Trajectory*

Given the new object and the new rule described above, each of rules 44, 45, and 46 can be simplified. For example, a simplified Rule Structure_Trajectory_Weapon is shown in Program Segment 4.

```
(defrule FIRES::Structure_Trajectory_Weapon
(declare (salience -5))
; match intermediate object
(object (is-a ConflictDueToBlockingBuilding)
            (buildingName ?building) (buildingLatitude ?fBLAT)
            (buildingLongitude  ?fBLONG) (buildingAltitude ?fBa)
            (buildingHeight ?fheight) (targetLatitude ?fTLAT)
            (targetLongitude ?fTLONG) (targetAltitude ?fTa)
            (munitionMaxSpeed  ?V) (weaponSelection ?oWS)
            (weaponRating ?nRATING) (weaponCons  ?lCONS)
            (ammoId  ?oMN) (weaponId  ?oLW))
(object (is-a WeaponSelection)(name ?oWS)( entityId ?oET))
(object (is-a LethalWeapon)(name ?oLW)(encyclopedic FALSE)
            (weaponAmmo ?oMN)(location ?WLoc))
(object (is-a TrackPosition)(name ?oWLoc)
            (latitude ?fENTLAT)(longitude ?fENTLONG)(altitude ?fSa))
(test (<> ?fENTLAT ?fENTLONG 0))
(test (InTheWay ?fENTLAT ?fENTLONG ?fBLAT ?fBLONG ?fTLAT ?fTLONG))
(test (not (member$ (str-cat ?building ", potential obstacle in
            trajectory path") $?lCONS )))
(test (> 0 (TrajectoryCheck ?fENTLAT ?fENTLONG ?fSa ?fBLAT ?fBLONG
            (+ ?fBa ?fheight) ?fTLAT ?fTLONG ?fTa ?V)))
=> … [same as the original rule]
```

Program Segment 4: *Simplified Rule Structure_Trajectory_Weapon*

Rules 45 and 46 would be similarly simplified.

A similar operation can be carried out on rules 47, 48, and 49 by introducing a new intermediate concept node, *ConflictDueToBlockingRotaryWing* and a new base rule. In fact the two new rules that we introduce can be further factored out because they are fairly similar except for the difference as shown in Program Segment 5.

Portion of rule for ConflictDueToBlockingBuilding:

```
(object (is-a RotaryWing) (encyclopedic FALSE)
      (referenceName ?chopter) (location ?oChopterPos))
(object (is-a TrackPosition) (name ?oChopterPos) (latitude ?fBLAT)
      (longitude ?fBLONG) (altitude ?fBa))
```

Portion of rule for ConflictDueToBlockingRotaryWing:

```
(object (is-a Structure)(referenceName ?building)
      (location ?oBuildingPos)(structureDimension ?oDimen))
(object (is-a Dimension)(name ?oDimen)(height ?fheight))
(object (is-a Position)(name ?oBuildingPos&~?oTargetPos)
(latitude ?fBLAT)(longitude ?fBLONG)(altitude ?fBa))
```

Program Segment 5: *Differences in rules for* ConflictDueToBlockingBuilding *and* ConflictDueToBlockingRotaryWing

Thus by formulating a higher-level intermediate concept node, in this example **ConflictDueToBlockingObject**, we can significantly simplify the design of sets of related rules. No doubt the designer had such a concept in mind while writing the these six rules that appear in the above cluster. However, because the domain ontology does not have the infrastructure for defining composite concepts, the deficiency manifests itself in the rules being unusually long and unreadable. Revelation of such higher-level concepts would have taken tedious manual inspection without our tool. We could have used the rule names as being suggestive of the similarity across the rules; however, the strength of our tool lies in exposing these similarities without depending on the rule naming conventions. Moreover, as we have seen above, sometimes a central concept like conflict for the cluster has not been mentioned even once in the rule name. Hence it is dangerous to base any conclusions on such a superficial examination. Such revelations from clustering the system can be exploited to restructure rules for readability and reorganize the ontology hierarchy in the object model. The contention is that such an exercise would in the long run make knowledge entry more efficient and reliable while increasing the run-time efficiency of system because bulk of the instantiations will have to be invoked only once for a set of rules.

3.3 Templatizable Clusters

In this section we show the templatization application of clustering in the context of the targeting and weapon capabilities addressed by IMMACCS. Clustering juxtaposes structurally similar rules that can be generalized and used to generate templates. Thus certain portions of the code can be treated like the constants of an equation common to the various instantiations; the rest are the variable parameters. Such templates can be used as an aid to high-level knowledge entry as we illustrate in a couple of examples below.

3.3.1 The *Targeting* Cluster

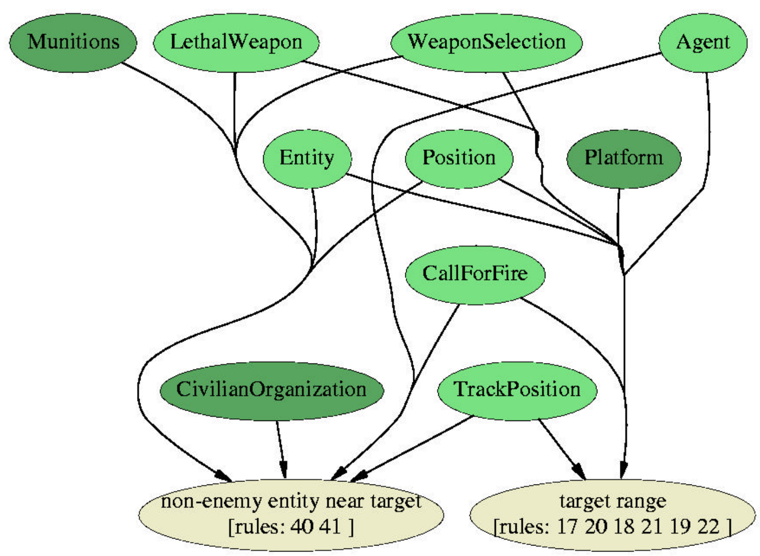

Figure 3: Term Usage for Targeting Cluster

Within the general concept of targeting we discovered two subclusters, as shown in Figure 3. The first subcluster, which we call **non-enemy entity near target**, has only two rules. These are applicable when non-enemy entities, such as civilians or friendly forces, are near a target. The second subcluster, which we call **target range**, has six rules dealing with targets being in or out of range. Figure 3 shows that many objects such as Lethal Weapon, Entity, Weapon Selection etc. are used by both conceptual clusters. However, Munitions and CivilianOrganization are used exclusively by **non-enemy entity near target** and Platform is used only by **target range**. Notice that the majority of the objects are accessed by both clusters.

The rules in the cluster are shown below and the template for the rules are given in Program Segment 6. The slots to be filled in the template are bold and in angle brackets.

```
FIRES::Friend_Unit_Near_Target
FIRES::Civilian_Entity_Near_Target
```

If a new type of non-enemy entity different from civilian or friendly forces is identified—say, a non-aligned force—this template can be used to put the rules in place very quickly by giving the filler slots values for the new setting. The basic skeleton is in place now to perform this function efficiently and reliably.

```
(declare (salience -5))
(object (is-a Agent)(name ?oFireAgent)(agentId "FIRES"))
(object (is-a CallForFire)(name ?oCFF) (targetLocation ?oTargetPos))
(object (is-a Position)(name ?oTargetPos)(latitude ?fTLAT)
            (longitude ?fTLONG))
(object (is-a WeaponSelection)(name ?oWS)(CFFId ?oCFF)
      (cons $?lCONS)(pros $?lPROS)(rating ?nRATING)
      (ammoId ?oMN)(weaponId ?oLW)(entityId ?oET))
(object (is-a Munitions)(name ?oMN)(CEP ?nCEP)(ECR ?nECR))
(object (is-a LethalWeapon)(name ?oLW)(weaponAmmo ?oMN)
      (location ?WLoc))
(object (is-a TrackPosition)(name ?WLoc)(latitude 0.0)
      (longitude 0.0)) <non-enemy-entity>   <optional-friend-code>
(object (is-a TrackPosition)(name ?oENTPS)(latitude ?fENTLAT)
      (longitude ?fENTLONG))
(test(and (not
      (member$ <non-enemy-entity-near-target-message> $?lCONS))
      (<= (kmDegDistance ?fENTLAT ?fENTLONG ?fTLAT ?fTLONG)
      (/ (+ ?nCEP ?nECR) 1000))))
=>
(bind ?d (DegDistance2 ?fENTLAT ?fENTLONG ?fTLAT ?fTLONG km))
(if (<= ?d 0) then (bind ?d 0.001))  <cep-binding>
(bind ?drating (* -15 (/ ?cep ?d)))
(send ?oWS put-rating (RatingPercentage ?nRATING ?drating))
(send ?oWS put-cons (insert$ $?lCONS 1
(create$ <non-enemy-entity-near-target-message>))))
```

Program Segment 6: *Template for the group* non-enemy entity near target

3.3.2 The *Weapons* Cluster

There are three major subgroups within the general concept of weapons: weapon capabilities, weapon timing and weapon presentation. The majority of the objects from the object model are used by the rules in these major subgroups. Due to the information overload in each rule, in order to understand the rules functionally, one has to draw meaning from the rules based upon their structure, that is, on *how* they are being used, and not just on *what* is the content. Here, MVP-CA aids us by exposing this usage information. Details of all the various groups and subgroups have been discussed in the ONR final report (Mehrotra 2001). In this paper we choose the weapon presentation cluster for templatization. The rules in this cluster deal with various aspects of weapon selection and weapon recommendation, concepts which form the two major subgroups. As evidenced by Figure 4, Weapon Selection uses Entity, Munitions and Platform whereas Weapon Recommendation uses the extra concept of Alert from the object model. This group merges the concepts of "weapon selection" and "weapon recommendation".

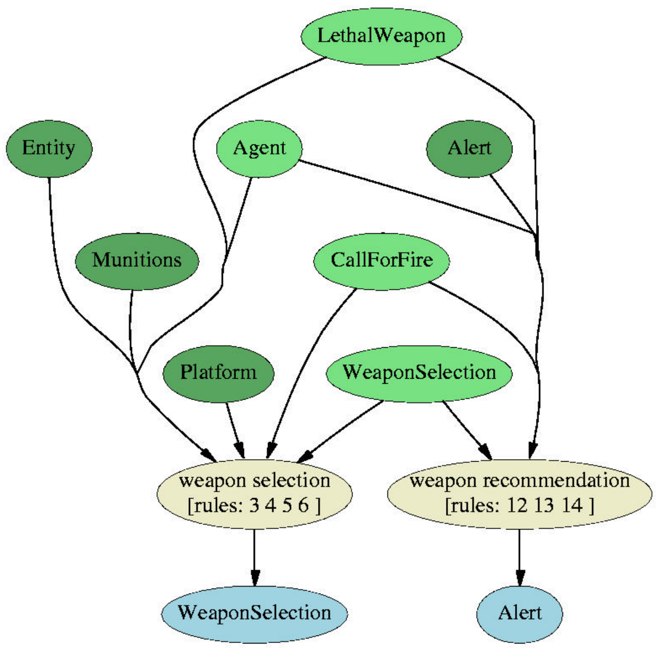

Figure 4: Term Usage for Weapon Presentation Cluster

The rules for weapon selection are

```
FIRES::Recommend_Best_Weapon
FIRES::Recommend_Feasible_Weapon
FIRES::No_Best_Weapon_Recommendation
```

And rules for weapon recommendation are

```
FIRES::WeaponSelection_NoPlatform_NoEntity
FIRES::WeaponSelection_NoWeapon_NoPlatform_NoEntity
FIRES::CreateWeaponSelection_Entity
FIRES::CreateWeaponSelection_Entity_Platform
```

Program Segment 7 shows a template for rules related to weapon recommendations. The rule **saliences** are set so a best weapon recommendation alert shows up before the list of feasible weapons. If there is no weapon recommendation, an alert to that effect shows up instead.

```
(declare (salience <salience>))
(object (is-a Agent)(name ?oFireAgent)(agentId "FIRES"))
(object (is-a CallForFire)(name ?oCFF))
?lw <- (object (is-a LethalWeapon)(name ?oLW))
(object (is-a WeaponSelection)(name ?oWS)(CFFId ?oCFF)
      (choice <specific-choice>)(rating ?nR1)(weaponId ?oLW)
      (ammoId ?oMN)(platformId ?oPF)(entityId ?oEN))
(not(object (is-a Alert)(alertAgent ?oFireAgent)
      (causeObjects ?oCFF ?oMN ?oLW ?oPF ?oEN)))
=>
(bind ?msg (WeaponSummary ?oWS))
(bind ?weaponName (send ?lw get-referenceName))
(make-instance (GetUniqueName Alert) of Alert
      (source "FIRES")(sourceReliability COMPLETELY)
      (referenceName (str-cat <recommendation-name> ?weaponName ))
      (alertMessage ?msg)(alertAgent ?oFireAgent)
(causeObjects ?oCFF ?oMN ?oLW ?oPF ?oEN)))
```

<specific-choice> can take the values:
Best, Feasible
<recommendation-name> can take the values:
Recommend_Best_Weapon, Recommend_Feasible_Weapon

Program Segment 7: *Template for* weapon recommendation

Another interesting cluster worth mentioning was obtained for weapon timing in the guided munitions cluster. The following rules were members of this cluster:

```
FIRES::Weapon_OnTime_Emergency
FIRES::Weapon_NotOnTime_Emergency
FIRES::Weapon_OnTime_Immediate
FIRES::Weapon_NotOnTime_Immediate
FIRES::Entity_Weapon_OnTime_Emergency
FIRES::Entity_Weapon_NotOnTime_Emergency
FIRES::Entity_Weapon_OnTime_Immediate
FIRES::Entity_Weapon_NotOnTime_Immediate
FIRES::Platform_Weapon_OnTime_Emergency
FIRES::Platform_Weapon_NotOnTime_Emergency
FIRES::Platform_Weapon_OnTime_Immediate
FIRES::Platform_Weapon_NotOnTime_Immediate
```

This cluster picks up rules related to various aspects of weapon timing: emergency, immediate, on time, or not on time. All rules in the above cluster follow the same naming pattern {Entity_,Platform_}_Weapon_{OnTime,NotOnTime}_ {Emergency,Immediate}. Many of the rules in this group are quite similar to each other, providing opportunities for templating and/or abstractions to higher levels of the ontology. For instance, if we compare the rule (FIRES::Weapon_OnTime_Emergency) and rule (FIRES::Weapon_NotOnTime_Emergency) we find that they are almost identical except for using opposite operators. This is a bit different from the examples of templating given in other observations (reference, for example, "non-enemy entity near target"). Most of those examples illustrate parallel concepts such as "civilians near a target" and "friendly forces near a target". Here, the concepts "Weapon_OnTime_Emergency" and "Weapon_NotOnTime_Emergency" are complementary rather than parallel. Parallel similarities occur between many of the rules, and are evident both through the rule naming covention and the clustering results.

4.0 Results from Inter-agent Clustering

In this section we present the results from clustering across agents in IMMACCS. Rules with striking similarities were found showing the role of clustering in exposing interoperability issues in the system, that is, functionalities that span across agents, and could perhaps impact future construction of similar systems. We found that clustering brought into focus rules across agents that had same rule names even though content was slightly different in each. When examined closely, each rule had been adapted just slightly for addressing the specialized behavior in their context. An example is presented in Program Segments 8, 9 and 10 for updating and acknowledging the Call for Fire Alert message. In the BLUEONBLUE and ROE agents the "causeObjects" object is referenced instead of the "affectObjects" as in the INTEL agent. The rest of the functionality across the rules is more or less similar, except for a few extra assertions being made in the consequent of the ROE rule for the SENTINEL agent. This proves that clustering can provide opportunities for higher level concept formation across agents. They can be considered as prime candidates for templatization as well, across various agents, thus addressing the need for functional abstraction when designing various agents.

```
(defrule BLUEONBLUE::UpdateAcknowledgedCFFAlertMessage
?agent <- (object (is-a Agent)(name ?agentName)(agentId "BLUEONBLUE"))
?cff <- (object (is-a CallForFire)(name ?cffName)
      (acknowledged TRUE)
      (targetNumber ?targetNum&:(neq ?targetNum "")))
?alert <- (object (is-a Alert)(source "BLUEONBLUE")
      (alertAgent ?agentName)
      (causeObjects $?causeObjects&:(member$ ?cffName ?causeObjects)))
=>
(bind ?msgFormat
      (str-cat(send ?alert get-alertMessage)
      "%n“ "+++ ACKNOWLEDGED +++%n""
      CallForFire has been acknowledged with%n"" target number %s"))
(bind ?alertMessage (format nil ?msgFormat ?targetNum))
(send ?alert update-slot alertMessage ?alertMessage)
(send ?alert update-slot acknowledged FALSE))
```

***Program Segment 8**: Rule for the* BLUEONBLUE *Agent*

```
(defrule INTEL::UpdateAcknowledgedCFFAlertMessage
?agent <- (object (is-a Agent)(name ?agentName)(agentId "INTEL"))
?cff <- (object (is-a CallForFire)(name ?cffName)
      (source "INTEL")
      (acknowledged TRUE)
      (targetNumber ?targetNum&:(neq ?targetNum "")))
?alert <- (object (is-a Alert)(source "INTEL")
      (alertAgent ?agentName)
      (affectObjects ?cffName))
=>
(bind ?msgFormat
      (str-cat(send ?alert get-alertMessage)
      "%n""+++ ACKNOWLEDGED +++%n""
      CallForFire has been acknowledged with%n"" target number %s"))
(bind ?alertMessage (format nil ?msgFormat ?targetNum))
(send ?alert update-slot alertMessage ?alertMessage)
(send ?alert update-slot acknowledged FALSE))
```

***Program Segment 9**: Rule for the* INTEL *Agent*

5.0 Concluding Remarks

In this project the feasibility of applying the MVP-CA tool to a multi-agent system was demonstrated. It has been shown that a semi-automated tool such as Pragati’s MVP-CA (Multi-ViewPoint Clustering Analysis) tool can provide valuable aid for comprehension, maintenance, integration and evolution of expert systems by structuring a large knowledge base in various meaningful ways. The similarity in existing rule bases can be exploited by the MVP-CA tool to "mine" the knowledge existent in them, thus paving the way for these systems to be elevated to becoming knowledge-centric, instead of remaining at the information-centric level. To achieve this goal, the knowledge in the system must be suitably abstracted, structured, and otherwise clustered in a manner that facilitates software engineering activities (Mehrotra and Barr 1998, Mehrotra et al. 1999a, Mehrotra et al. 1999b). Hence, by exposing the knowledge contained in knowledge-based system through the Multi-ViewPoint Clustering Analysis tool, we formulate a basis for addressing reusability, maintainability, and reliability issues for such systems.

Clustering showed that the strong similarity across groups of rules can be exploited to build more hierarchically organized rules. It also showed how to reorganize the object model to suit the application demands in terms of slight variations on base concepts and how to discover as well as relieve some of the pressure points in the declared object model. Creation of intermediate concept nodes abstracts common functionalities and allows the user to think in terms of higher-level concepts and goals. Clustering also helps to identify under/over-used concepts across agents which may be over/under-specified in the object model and make proper adjustments to the ontology or the rules. Formulation of templates can help facilitate new knowledge acquisition and long-term maintenance of the rules. Most importantly, clustering aids in the identification of common functionalities across agents and the identification of reusable components in the knowledge base, thus addressing interoperability issues in the system.

```
(defrule ROE::UpdateAcknowledgedCFFAlertMessage
(object (is-a Agent)(name ?agentName)(agentId "ROE"))
?cff <- (object (is-a CallForFire)(name ?cffName)
      (acknowledged TRUE)
      (targetNumber ?targetNum&:(neq ?targetNum "")))
?alert <- (object (is-a Alert)(source "ROE")
      (alertAgent ?agentName)
      (causeObjects $?causeObjects&:(member$ ?cffName
?causeObjects)))
=>
(bind ?msgFormat (str-cat(send ?alert get-alertMessage)
      "%n""+++ ACKNOWLEDGED +++%n""
      CallForFire has been acknowledged with%n"" target number %s"))
(bind ?alertMessage (format nil ?msgFormat ?targetNum))
(send ?alert update-slot alertMessage ?alertMessage)
(send ?alert update-slot acknowledged FALSE))
(deffacts MAIN::SENTINEL_Facts
(SENTINEL_RED_RANGE_METERS 4000.0)
(SENTINEL_CFF_RANGE_METERS 500.0))
```

***Program Segment 10**: Rule for the* ROE *Agent*

6.0 Future Work

Having shown the feasibility and usefulness of clustering a multi-agent command and control system such as IMMACCS, we are now poised to study the design issues to be considered for building reusable, interoperable ontologies. Even though the goal of an ontological engineer is to try and formulate the ontology in a general manner, in reality, the design issues in an ontology are influenced by the need to solve the problem at hand in an optimal fashion. Hence, an ontology written for a specific problem slants the views in the ontology towards being efficient at formulating the problems in that class. The level of detail for an object definition, object type specification, an object's placement in the ontological hierarchy to reflect its relationships to other objects in the ontology, all get influenced by the overall problem solving goals for the agent(s) that will use the ontology. This implicit bias poses a problem for reuse of the ontology for subsequent projects, in which agents have to often deal with a slight shift in focus on the problem solving aspects, while using a domain similar to the previous project.

Due to the existence of biases in the existing ontology's perspective, a new problem will likely be formulated in the old framework clumsily at best; in some cases, it may note be possible to formulate the problem at all. The good news is that ontological engineers can often provide insight into the types of modifications needed to render the old framework reusable for the new problem. However, the cost of understanding the complexities in the current ontology, recasting the new problem in the old framework and then deciding what changes should take place in the old ontology to effect a natural problem formulation, is an expensive proposition. The frequency with which old ontologies need to be recast as well as the extent to which they need to be recast, warrants that a high level approach be taken towards semi-automating some of the ontology redesign tasks. The focus of our future work will, therefore be to create a software support environment for building and reusing ontologies so that the cost of ontology design in multi-agent systems is amortized over several different projects. The MVP-CA tool will help guide the design process by revealing important hidden relationships across objects in existing ontologies, so that they can be made explicit and usable for future construction of intelligent agent-based systems.

References

(Chandra 1986) B. Chandrasekharan. Generic tasks in knowledge-based reasoning: High-level building blocks for expert systems design. IEEE Expert, Fall 1986.

(Mehrotra 1994) M. Mehrotra. Application of multi-viewpoint clustering analysis to a highway maintenance system. AAAI-94 Workshop on Verification, Validation and Testing of Knowledge-Based Systems, August 1994.

(Mehrotra and Wild 1995) M. Mehrotra and C. Wild. Analyzing knowledge-based systems using multi-viewpoint clustering analysis. Journal of Systems and Software, 29:235-249, 1995.

(Mehrotra 1995) M. Mehrotra. Requirements and capabilities of the multi-viewpoint clustering analysis methodology. In Notes for the IJCAI-95 Workshop on Verification, Validation and Testing of Knowledge-Based Systems, Montreal, Canada, August 1995.

(Mehrotra 1995b) M. Mehrotra. Radar Signal-Processing Rulebase Partitioning. Technical Report RL-TR-95-50, Rome Laboratory, Griffiss Air Force Base,N.Y., March 1995.

(Mehrotra 1996) M. Mehrotra. Application of multi-viewpoint clustering analysis to an Expert Systems Advocate Advisor. Technical Report FHWA-RD-97022, Federal Highway Administration, Pragati Final Report, Yorktown, VA., August 1996, (Can be obtained as an NTIS report for the Federal Highway Administration).

(Mehrotra and Barr 1998) M. Mehrotra and V. Barr. *Application of Clustering Analysis to Coverage Testing for Large KBS*. Validation, Verification and Testing of Knowledge-Based Systems in the AAAI Conference, July, 1998, Madison, Wisconsin.

(Mehrotra 1999) M.Mehrotra. A Semantic Approach Towards Software Engineering of Knowledge Bases. AAAI-99 Intelligent Software Engineering Workshop, July 19 1999. Florida. http://sunset.usc.edu/GSAW/1999.

(Mehrotra et al. 1999a) M. Mehrotra, S. Alvarado and R. Wainwright. Laying a Foundation for Reusability of Knowledge Bases in Spacecraft Ground Systems. Proceedings of the Ground Systems Architecture Workshop, March 3-5. GSAW 99. The Aerospace Corporation, El Segundo, CA.

(Mehrotra et al. 1999b) M. Mehrotra, S. Alvarado and R. Wainwright. Laying a Foundation for Software Engineering of Knowledge Bases in Spacecraft Ground Systems. Proceedings of FLAIRS99 Conference. Special Track on AI Applied to Spacecraft Autonomy, Florida.

(Mehrotra 2001) M. Mehrotra. Multi-ViewPoint-Clustering Analysis (MVP-CA) Technology for Analaysis of IMMACCS. Final Report. ONR Contract #: N00014-00-M-0205.

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SEAWAY Supply Mission Scheduling Using Computational Intelligence

R. C. Eberhart, X. Hu, C. Wen, and Z. Ben Miled

Electrical and Computer Engineering Department
Purdue School of Engineering and Technology
Indiana University Purdue University Indianapolis
723 West Michigan Street
Indianapolis, IN 46202-5132

Abstract

SEAWAY is an ICDM-based decision support application. A computational intelligence based planning agent is described that optimizes delivery of supplies according to a statement of requirements to a number of operational units onshore from a sea base. The statement of requirements contains required items, priorities, and time windows. A preliminary version of the planning agent that uses evolutionary computation has been demonstrated. This approach allows rapid planning, and rapid re-planning as the situation changes.

Keywords

SEAWAY, computational intelligence, evolutionary computation, planning agent.

Introduction

SEAWAY was developed as an ICDM-based decision-support application. ICDM provides a formalized architecture with a set of development and execution tools that can be utilized to design, develop, and execute agent-based, decision-support applications. The ICDM model has three layers, which are defined as illustrated in Figure 1. CDM Technologies, San Luis Obispo, California has coordinated and led SEAWAY development, including development of the ICDM model.

Computational Intelligence

Computational intelligence is a process or methodology involving computing (usually involving a computer) that exhibits an ability to adapt to new situations, and/or to self-organize, such that the system is perceived to possess attributes such as reason, decision, prediction, implication, and intention. Capabilities of a system with computational intelligence may include generalization, discovery, abstraction, and/or association. Put another way, computational intelligence comprises practical *adaptation and/or self-organization* concepts, paradigms, algorithms, and implementations that enable or facilitate intelligent behavior in complex and changing environments (Eberhart et al. 1996).

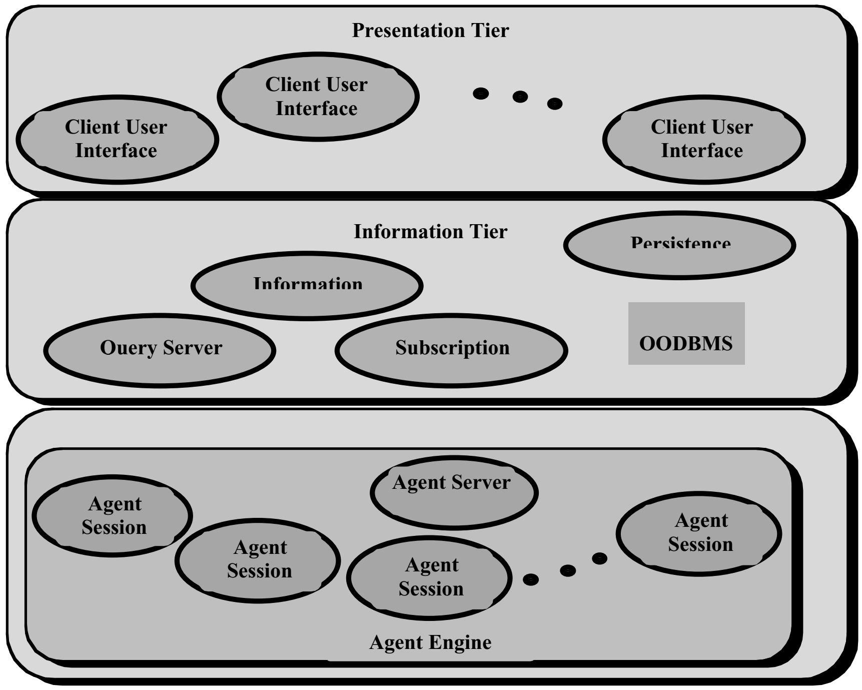

Figure 1: ICDM system architecture

Computational intelligence systems in silicon often comprise hybrids of paradigms such as artificial neural networks, fuzzy systems, and evolutionary computation systems, augmented with knowledge elements. Computational intelligence silicon-based systems are often designed to mimic or augment one or more aspects of carbon-based biological intelligence.

Evolutionary computation (EC) comprises adaptive optimization and classification paradigms roughly based on mechanisms of evolution such as natural selection and self-organization. The evolutionary computation field includes genetic algorithms, evolutionary programming, genetic programming, evolution strategies, and particle swarm optimization.

Primary application areas of EC include:

- Optimization: finding the best possible solution to a complex problem (often NP hard) in the specified time.
- Classification: operating in multiple-fault dynamic environments.
- Explanation: providing explanation facilities for systems such as complex artificial neural networks

We view evolutionary computation as providing a foundation for computational intelligence. It seems to us to be in some sense the mortar that holds the bricks together. All of our recent applications involve evolutionary algorithms *plus* other components; the evolutionary paradigm is always present.

An artificial neural network (ANN) is an analysis paradigm that is roughly modeled after the massively parallel structure of the brain. It simulates a highly interconnected, parallel computational structure with many relatively simple processing elements (PEs) (Eberhart et al. 1996). ANNs are able to approximate any non-linear function to any specified degree of accuracy.

Primary application areas of ANNs include:

- Classification as reflected in decision theory: determining which of a set of predefined classes best represents an input pattern.
- Associative memory: obtaining an exemplar pattern from a noisy and/or incomplete one.
- Clustering, or compression: significantly reducing the dimensionality of an input.
- Control systems: modeling a non-linear system as well as designing the control system.
- Simulation: generation of structured sequences.

Fuzziness refers to nonstatistical imprecision and vagueness in information and data. Fuzzy sets model the properties of imprecision, approximation, or vagueness. In a fuzzy set, fuzzy membership values reflect the membership extents (or grades) of the elements in the set. Fuzzy logic comprises operations on fuzzy sets, including equality, containment, complementation, intersection, and union; it is a generalization of crisp (two-valued) logic.

Primary application areas of fuzzy systems include:

- Control systems: controlling complex systems in real time.
- Fuzzy expert systems: providing support in diagnostic and decision support systems

For more complete discussions of computational intelligence, see (Eberhart et al. 1996) and (Eberhart et al. 2000).

Objectives

From the SEAWAY proof-of-concept definition (CDM Technologies, Inc. 2000), the scheduling agent is a future-plan agent, which is an agent session in the agent engine tier. It supports the satisfaction of logistical requirements through supply mission planning. However, there is no pre-determined performance objective. The performance can be evaluated from following perspectives:

- Time of schedule optimization.
- Dynamic scheduling. The agent can reschedule the delivery based on current progress.

- Based on critical resources, there can be several optimization goals, for example, shortest time, and shortest path. For this project, the critical resources should be the number of assets and the time window of the supply points. So the maximum weighted quantity of supplies delivered is one kind of optimization goal.

This intelligent scheduling agent is a part of the SEAWAY system and will be incorporated into the SEAWAY system as an agent session. More exactly, this capability exists as an *app.agent.MentorAgent* agent.

The project staff at the Purdue School of Engineering and Technology at IUPUI includes Prof. Russell Eberhart (PI), Prof. Zina Ben-Miled (Co-PI), Prof. Yaobin Chen (Consultant), Xiaohui Hu, (Ph.D. Candidate), and Chen Wen (Graduate student).

Framework

Similar to the architecture of SEAWAY project, this scheduling agent can be divided into three layers: the interface layer, the translation layer, and the agent layer. Figure 2 shows the layers of the process.

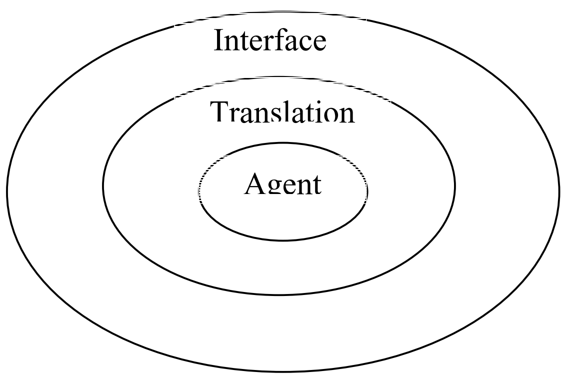

Figure 2: Architecture (layers) of the scheduling agent.

The interface layer deals with the communication between the scheduling agent and other parts of the SEAWAY system or possible user interfaces.

The translation layer is a pre-processing and post-processing step. It communicates between the SEAWAY data and the parameters of scheduling agent, for example, distance between any two points, speed of assets, and loading and unloading times. Other factors such as weather parameters are transferred into the parameters in this level. It also translates the result into a format the other parts of SEAWAY can understand.

The central agent layer is the schedule optimization agent that implements the core algorithm. Only standardized parameters are used for the algorithm. The process can be used for a wide variety of problems, i.e., the agent can be generalized to other kinds of scheduling problems.

Agent Algorithm

In order to get an optimal or near-optimal result, there are several points in the scheduling system that need to be tuned:

- Item delivery sequence. This is the main scheduling objective.
- Asset s behavior. When loaded, what kind of delivery strategy should the asset adopt to obtain a better result? Strategy examples are loading sequence, priority sequence, and quantity sequence.
- Base point-landing rules. Each base point has its own limitations, for example, limited landing positions for assets.

For a scheduling system, there are a variety of approaches to accomplish the optimization (Cormen et al. 1990):

1. Linear algorithms, such as greedy algorithms, Dijkstra s algorithm, Kruskal s algorithm, Prim s algorithm, etc.
1. Expert systems.
1. Computational intelligence (CI) tools such as genetic algorithms and particle swarm optimization.

Linear algorithms refer to traditional ways to achieve the optimization based on detailed established mathematical models. For example, greedy algorithms assume the problem has two properties: a greedy-choice property and optimal structure, which are not easy to establish in this class of problem. Furthermore, when the conditions are dynamic (as they always are in this kind of problem), the model has to be re-established to accommodate the changes.

An expert system is a computer application that performs a task that would otherwise be performed by a human expert . For example, there are expert systems that can diagnose human illnesses, make financial forecasts, and schedule routes for delivery vehicles. Some expert systems are designed to take the place of human experts, while others are designed to aid them. To design an expert system, one needs a knowledge engineer, an individual who studies how human experts make decisions and translates the rules into terms that a computer can understand. For this scheduling problem, it is not easy to get the knowledge from the scheduling system and it is also time-consuming to develop rules. More important, it is not suitable for dynamic systems, in which things always change unexpectedly. Traditional expert systems are also brittle. If conditions move outside their domain of expertise, they can fail catastrophically.

Now we look at CI tools. The optimization of asset behavior and base point landing rules can be predetermined, so the optimization is the main problem, and for a given environment there should be an optimal item delivery sequence. Therefore we can use computational intelligence tools to find an optimal or near-optimal solution, which could not be done by linear algorithms. Computational intelligence tools are an important means to solve non-linear problems. Possible solutions include genetic algorithms, genetic programming, evolution strategies, evolutionary programming, and particle swarm optimization. They share some common procedures in that they all generate an initial group of candidate solutions. The second step is to calculate the fitness values of the candidate solutions. Based on their fitness values, the system generates a new group of solutions according to some rules. The last step is to check if each solution meets the requirements; if so, the solution is acceptably near to the optimum; otherwise, the system goes back to the second step to repeat the procedure.

Consider the characteristics of the scheduling agent, using a genetic algorithm as the approach. Genetic algorithms are a kind of optimization technique for functions defined in finite domains. All the possible solutions are mapped or encoded to a finite string. The algorithm will manipulate the string instead of the original problem.

The two key points in the GA implementation are the solution encoding and the fitness function. In our problem, the solution is an optimized cargo delivery sequence. If every cargo item is given a number, the solution is a number sequence that can be represented by a finite string. Fitness values are computed for each individual of each population, and the values indicate how close the individuals are to the optimum. Based on the fitness values, the algorithm tries to update the population and finds the best fitness value for the problem. In this scheduling system, the fitness function can be a simulation process, which simulates the whole transferring process based on a given delivery sequence. In our case, the simulation result metric is how many missions have been completed. This is the fitness value of the sequence. Then we use genetic algorithm rules to generate the next generation of the population. By repeating the process, we can approach and find the optimum or acceptable near-optimum.

Summary of Work Accomplished

Our current work is mainly based on a demonstration scenario provided by CDM Technologies, San Luis Obispo, CA. They provided the following information:

In the demonstration scenario, one sea base vessel sits approximately 50nm off the shore. We have one supply point on shore and we have two supply points inland. Assume a 50 nm distance between the sea bases and the shore-based supply point and assume a 75 nm distance between the sea base and the inland supply points. We have access to two types of transports, CH-53E helicopters and LCAC air-cushion transports. The CH-53Es can travel to either the shore or inland supply points, while LCACs can only travel to the shore supply point. We will have five units to supply (Unit 1 through Unit 5), but we will only deliver items to supply points, not to the actual unit location (requirements will state when a unit can receive cargo at a specific supply point).

The objective of the first stage of the project is to develop a prototype of the scheduling agent. We have not incorporated detailed information about the SEAWAY architecture and interface standards, so our focus is on the agent layer of the project, the algorithm.

The current system was developed on Java2 SDK 1.3. It includes over 20 source code modules. The majority of the code comprises the simulation process, i.e. the process used to maximize the fitness function of the algorithm based on the given demonstration scenario. However, it is designed to have a great expandability and could be used for other similar kinds of scheduling systems. There are three main class types: start point, end point, and asset. Start point classes (e.g., seabase.java) deal with arranging and loading of cargo items, asset classes are kinds of transportation tools to move cargo items from start point to end points, and end point classes deal with the unloading of cargo items.

For the starting point, the cargo item delivering sequence is determined by outside algorithms such as linear algorithms, expert system or CI tools.

The asset manages the cargo items on it and tries to move it to the end point. The following is the status transfer diagram of the assets:

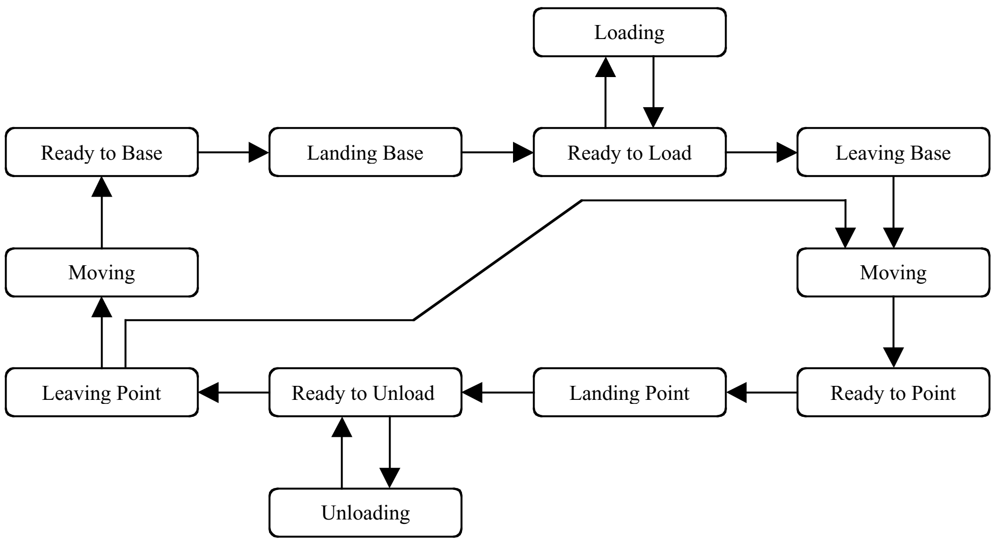

Figure 3: The status transfer diagram of an asset

After the end of the simulation, the simulation results are used to calculate the final fitness value for the given delivery sequence.

The main (or entry) class for the simulation is PSETMain.class. To run the simulation, then, from within a Java environment, run *path*\\java PSETMain, where *path* is the path to java.exe, and PSETMain.class is in the current directory.

A simple graphical user interface (GUI) was also developed for demonstration purposes, which shows the simulation process working, alongside a tabular list of asset activities. The list shows what is happening to each asset on a minute-by-minute basis. The user can choose which asset to view, and select the time interval between graphical updates on the screen. The default time between updates is 1,000 ms (one second). The user can specify a different time interval in milliseconds. For example, if it is desired to speed up the graphical presentation, the time interval can be shortened to 250 milliseconds or some other value less than 1,000.

The user can also specify the loss of an asset during the simulation, and the time at which the asset is lost. The algorithm runs as though all assets will be available for the entire simulation up to the time the asset is lost. A new schedule is then generated, optimizing the scheduling of the remaining activities without the lost asset.

Since the project software was written in Java, the documentation capability of JDK1.3, called Javadoc, was used to provide the primary software documentation. Javadoc provides a series of HTML files, one for each Java class plus an index HTML file. To begin viewing the software documentation, it is suggested that the user click on the index.html file.

Future Activities

The next work tasks defined for the project are to:

1. Refine the algorithm. Compare different types of computational intelligence tools and tune the parameters of the algorithm. A version that allows selection of a greedy algorithm, a genetic algorithm, or particle swarm optimization will be available soon.
2. Incorporate the capability to change the statement of requirements during a simulation.
3. Plug the agent session into the main SEAWAY platform (code).
4. Apply the approach to other aspects of SEAWAY.

Acknowledgments

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References

1. CDM Technologies, Inc. (2000); SEAWAY Proof of Concept: Technical Guide.
2. Cormen, T. H., Leiserson, C. E. and R. L. Rivest (1990); Introduction to Algorithms; MIT Press, Cambridge, MA.
3. Eberhart, R. C., Dobbins, R. W. and P. K. Simpson (1996); Computational Intelligence PC Tools; Academic Press Professional, Boston, MA.
4. Eberhart, R. C., Chen, Y. and J. Zhang (2000); Computational intelligence for decision support; Proc. ONR/CADRC Decision Support Workshop, Office of Naval Research.
5. Kennedy, J., Eberhart, R. and Y. Shi (2001); Swarm Intelligence; Morgan Kaufmann Publishers, San Francisco, CA.

Project Albert + ROLF 2010 = Red Orm

Dr. Alfred G. Brandstein, Senior Advisor/Senior Analyst, MCCD
Dr. Henrik Friman, The Swedish National Defence College
Dr. Gary Horne, The MITRE Corporation

Introduction

In October 1995, at the direction of the Commanding General of the United States Marine Corps Combat Development Command in Quantico, a handful of Marines and civilian scientists embarked on what is now called *Project Albert*. The fact that this date coincides with the beginnings of *ROLF 2010* is not remarkable in and of itself. However, we believe that the intersection of the two efforts could, perhaps, turn out to be a collaboration remarkable not in coincidence, but in relevance. The two efforts, vastly different in focus, location, and methodology could, in combination, become a canonical example of non-linearity or at least exhibit the archetypical hallmark of non-linearity: the sum >> the parts.

This combination is still in the making and should not be construed at this point as anything other than a developing idea. But it has actually matured to the point of having a designation and has been named after the Viking exemplar of maneuver warfare: *Red Orm*. Here we ll summarize *Project Albert* and *ROLF 2010* before describing how they come together in the *Red Orm* project.

Project Albert

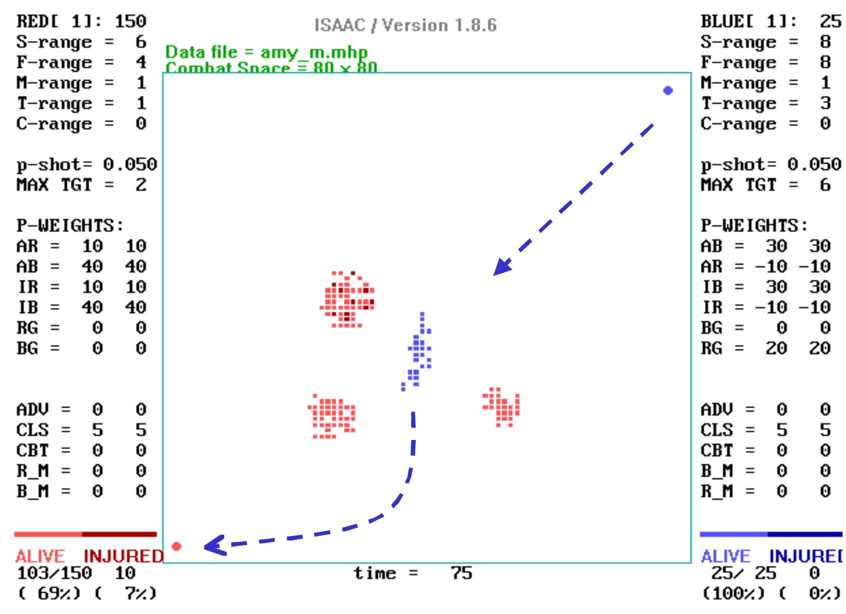
Project Albert uses a series of new models and tools, multidisciplinary teams, and the scientific method to explore questions. The approach utilizes the meta-technique called *data farming* to look at 21st Century questions from the perspective of the whole and lots of data points are needed to explore this whole . This meta-technique has been made possible by a convolution of advancements including:

- Advances in agent-based models, i.e. distillations, which have the promise of capturing some of the adaptability and other key factors inherent in conflict.
- Advances in computing power, which enables us to increase our volume of data.
- Advances in our ability to organize, analyze, and visualize scientific data.
- Advances in concepts on how to integrate across the spectrum of operations research techniques.

Project Albert is a research effort, which embraces the process of *Operational Synthesis*; the focus is on looking at the whole rather than reducing systems into parts. This process is a complement to traditional Operations Analysis it supports the study of asymmetries, risks, and potentials through the use, *inter alia*, of distillations. In summary, *Project Albert* is designed to develop new tools to capture emergent behavior in synthetic environments that over time will lead to more effective maneuver warriors.

Articles in reference [1] as well as this book describe some initial efforts by the Marine Corps to understand the potential mesh of the nonlinear sciences and complex adaptive systems with the study of warfare. One such effort is the development of an agent-based model called ISAAC, a mobile cellular automata model in that the individual fighting entities, called agents, move through a lattice and carry information with them as they go. The agents are given characteristics which include: a default local rule set specifying how to act in a generic environment, goals directing behavior, sensors generating an internal map of environment, and an internal mechanism to alter behavior. The figure below is a snapshot (with arrows added) of the ISAAC distillations. We have ported ISAAC to the Maui High Performance Computer and run it many millions of times as part of a process we call *Data Farming*, described earlier in this book. Briefly, what we try to do is grow data in the area of interest that provide insight into the answers to our questions. The fundamental underlying principal here is that we need to look at a vast landscape of possibilities because of the uncertainty inherent in and the nonlinear nature of conflict. Thus our research so far has concentrated on methods to create, access, and understand large amounts of data from distillations.

Figure. ISAAC snapshot.



In the ISAAC distillation depicted above, the first group of parameters represents capabilities such as sensor and fire range. The next group of parameters, or p-weights, represents the personalities of the agents, or how they will move and select strategies. This is done by inputting a set of weights, which are used to rank possible moves according to the agent s proximity to the various types of agents and goals. The other inputs represent another tier of adaptability, perhaps sociology, whereby the default personality is altered according to local threshold constraints. And finally, below the dark lines we see a tally of alive and injured agents one hit creates an injury and two removes the agent from the play.

Reference [1] describes some of the initial research efforts using ISAAC. One of the key areas of research is the examination of the role of intangibles such as cohesion, trust, and leadership in warfare. It should be stressed that these efforts are merely illustrative to this point. However, next generation distillations are now being tested at Quantico and at the Maui High Performance Computing Center and research has started on applying new distillations in real ways to real questions.

Rolf 2010

ROLF stands for "R rlig Operativ LedningsFunktion", in Swedish. Translated into English this means " Mobile, Joint Command and Control Function for the year 2010". ROLF suggests that small mobile units carry out overall joint command and control. The concept is not intended solely for combat applications, but has also been discussed for other uses, particularly within the field of total defence, e.g., for commanding peacetime rescue operations, and international operations. Details of ROLF can be found in reference [2]. Here we will describe three aspects of ROLF that we think likely differ from other concepts. First, the ROLF staff is quite *small*, a second difference is the *seating*, and the third is the nature of the *display.*

The staff concept should be seen as a network of centers for excellence rather than individual cells of staff being united. Specifically, this means that different nodes, staff elements, in this network will work with different issues concurrently. In the initial architecture the intention is that a complete staff unit will include at least four staff elements. In order to create a robust network, there are a number of small and mobile elements that are less vulnerable than the traditionally big staff units. However, the size has certain implications.

- Despite its smaller size, the ROLF staff still must do almost the same work as a traditional staff. The interconnections made possible by modern information technology may support this workload and relieve the staff of much of the need for co-ordination of the units.
-
- Work in the ROLF staff is likely to be quite intense, requiring a number of shifts. This highlights the attendant problem of keeping continuity of command and control action despite the changes in personnel.

The complexity and the dynamics of the command and control situation for a ROLF staff are assumed to create high uncertainty. It is reasonable to believe that no human could manage this environment by himself, and thus expert knowledge and competence must be instantly accessible. Other resources can be accessed through the net. In order to handle the situation a management team must be seated close together, in this case around the same table. The seating is chosen to facilitate the co-operation. We think that the seating around the same table will create at least two different advantages in handling complexity and dynamics.

- we believe that *successful communication* under the stressful conditions of battle is close and physical. This is the form of seating that humans have always chosen when they have serious matters to discuss, from the gathering of the early stone age people around the camp fire to the conference tables of modern board rooms. Serious discussions are possible only if psychological distance is minimised. There must be an opportunity for full communication, including body language and eye contact in order to gauge the mental state of the other persons in the staff.
-
- the seating creates a *common focus*. There is a common display of the situation that the staff members can refer to in their discussions. This should facilitate the development of shared situational awareness.

In order to illustrate and visualize the situations in different perspectives over time in a collective image in front of each participant in the staff element or in a number of elements, ROLF deviates from traditional means of combat representation. Traditionally, in the military environment there is a presentation of a 2D map that shows the so-called *battle room*. We believe that it is possible to present more informative situation maps by using new technologies and 3D, as well as multimedia techniques. This will improve not only the support for a trained group of individuals but also, hopefully, the perception of less highly trained people such as media representatives and politicians. The two main reasons for searching for new forms of presentations are:

- At the same time as 3D solution is assumed to improve the perception, they also involve the risk of adding complexity. In our view, the need for a 3D display is a consequence of the concept of *battle space*. The battle space concept refers to a *volume*, rather than a *surface*. The fact that the battle space must be constructed mentally by each staff member raises the possibility that different staff members may construct different representations and this in turn may lead to misunderstandings. There may be little chance of sorting out these misunderstandings during the hectic pace of modern battle.
-
- To support the decision process by improved ability to interact with the presentation. This is enabled by manipulation of the symbols in the representation directly by grabbing and moving them around and illustrating one s conception of the possibilities for action in the battle space. This is assumed to facilitate the dialogue between the participants in the environment, in the room as well as elsewhere in the network.

Red Orm

Red Orm seeks to significantly advance the state of the art in command and control. It focuses on *human* decision making processes, vice *techno*-centric decision environments. As such, its objectives are to discern, investigate and leverage key attributes of the decision-making milieu:

- non-linearities of warfare — *the influence of initial conditions and dynamics inherent in conflict*
- intrinsic human characteristics of warfare — previously *unquantified attributes of fighting forces (e.g., trust, leadership, elan, fear,)*
- co-evolving landscapes — *the codependent adaptation of forces within the crisis-space*

- crisis learning processes— *adapting behavior to leverage own strengths and exploit opposing weaknesses to optimize mission accomplishment*
- crisis-space uncertainty and complexity — *effectively managing and exploiting the fog and friction of conflict and crisis*
- multi-dimensional reasoning —*the human affinity for spatial environments, symbolic representations, common understanding of the crisis-space, and behavioral connotations in command team decision making*
- time criticality — the preeminence of the temporal domain in crises and an awareness of the time-uncertainty trade-space

In support of the above *Red Orm* objectives, the plan is to mutually extend and collaboratively integrate current areas of research to generate a prototype command and control laboratory. Prototype development will be achieved through a process of evolutionary enhancement. The American partner will apply their expertise in *data farming* and new methods of modeling and simulation. This will be extended to encompass multi-resolution/variable granularity command behaviors, planning, course of action analysis, and crisis-space characterization and response, all augmented by high performance computing. The Swedish partner will apply their expertise in innovative command and control environments. This will be extended to encompass development of interactive, multi-modal, aspect-dependent, human-centric perception tools for command and control settings.

In summary, we anticipate that in *Red Orm* the two partners will cooperatively investigate and develop user interfaces that integrate *Project Albert* and *ROLF 2010* efforts, hopefully culminating in a working laboratory that will enable accelerated command and control innovation by both parties. And, in conclusion, we state our ultimate goal: to develop better ways to make decisions in support of maneuver warriors.

References

[1] F. G. Hoffman and Gary E. Horne, Eds. *Maneuver Warfare Science 1998*. Quantico, VA: Marine Corps Combat Development Command, 1998.

[2] Claes Sundin and Henrik Friman, Eds. *ROLF 2010 A Mobile Joint Command and Control Concept.* Stockholm: Swedish National Defence College, 1998.

Designing Communications Software for Tactical Wireless Networks

Thomas McVittie, Ph.D.
Mission Software Systems
Jet Propulsion Laboratory,
California Institute of Technology.

Email: mcvittie@jpl.nasa.gov

Abstract

COTS middleware services promise to provide developers a high level platform that can be used to easily create distributed system that will run on any platform and across any network. While these middleware services work reasonably well on commercial wired networks, they can provide unacceptable levels of service when used on tactical networks. Our experience over the last four years shows that the causes of many of these failures is often related to a subtle interaction between the distribution model used by the middleware service, the underlying communication protocols it uses, and the transport services which are well supported by the tactical network. Re-implementation of specific key communication services components can be used to overcome many of these difficulties while continuing to use other middleware services unchanged.

This paper discusses the implementation and evolution of a COTS middleware-based information distribution service supporting the distribution of a military Common Tactical Picture across existing and experimental military tactical networks. It presents lessons learned fielding selected middleware architectures and proposes additional services that should be considered in future middleware implementations.

1 Overview: Powering A Revolution

Recent years have seen significant changes in how we collaboratively share information using distributed computing systems. As recently as fifteen years ago, systems tended to be developed on large isolated machines with dedicated client access. Data was shared between systems by either using very primitive internal networks or more often by sneaker-net[1]. Organizations wanting/needing to share information more widely would occasionally band together to create dedicated networks providing a limited connectivity between key nodes (ARPA-net is an excellent example). As a result, data and information were very difficult to share or even locate.

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[1] Sneaker-net refers to the process where a computer operator copies the file to be shared onto a disk and then walks it over to the other machine where it is uploaded.

Today s computing environment is very different. Significant increases in computing power and computer manufacturing allow computers to be commonplace appliance on both office and home desktops. Extremely capable networks, able to move a wide variety of information with relative ease, interconnect these same homes and offices. Data and information are rapidly becoming generally available commodities. Tools (such as search engines and web browsers) enable school children to locate and search data repositories for information of interest. Other tools (such as web servers, and applications servers) allow individuals and corporations alike to create their own data repositories which they can share as they see fit. These changes have had a profound impact on how we access and share information, and even on simple day-to-day tasks. For example, determining the current price of a stock 15 years ago would have required either a call to your broker, or installation of a fairly expensive dedicated ticker. Today this information is readily available from your browser as either a limited free service, or as an enhanced (say real time) pay-for-service commodity.

While these changes are phenomenal, they are only a precursor of the next age in which we are able to share information rather than just data.

2 Building Block Approach

The revolution in how we share data and information was a result of several significant developments. Any of these developments on their own would be important, but all of them together provide a much more powerful environment for building information/data sharing systems. The five most significant developments include:

- Powerful & Affordable Computing Resources
- Widely available & highly Interconnected Networks.
- Generic and Simple Data/Network Protocols (e.g., IP)
- Simple and Generic Transport/Application Protocols (e.g. SMTP, IIOP, HTTP, FTP)
- Application Services (e.g., CORBA, Web Servers)

The last three are of significant interest and are shown in Figure 1.

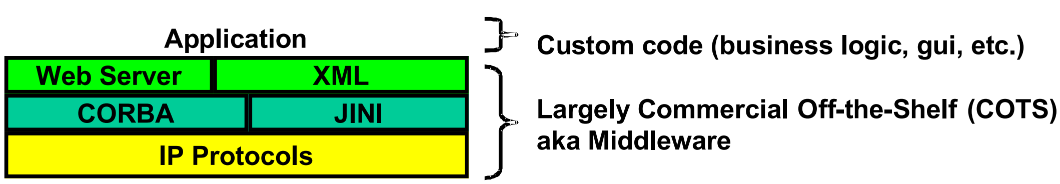

Figure 1. Typical Development Stack

While physical networks (such as phone lines) were readily available, the process of writing/validating a protocol that would run over a variety of different networks (e.g., Ethernet, frame-relay, ATM, token ring, etc.) was arduous. The **Internet Protocol (IP)** provided a generic and very capable set of primitive services that allowed information to move between systems. More importantly, it provided an abstraction layer that allowed packets of data to move between different types of networks, and alleviates programmers from having to deal with the internals of the physical network. Rather, they could spend their efforts on the applications rather than on the network.

However, even IP wasn t enough to engender the revolution. In the past 10 years, a set of very simple, but again powerful, transport and application protocols have been built which build upon the foundation of IP. Protocols such as HTTP implement a generic request-receive protocol where the client sends a request (in a specific format) to a server that processes the request and sends the data back to the client (again in a specific format). FTP is a similar service, but one specifically targeted to file transfer. SMTP likewise is responsible for moving email between machines. Other services such as the Internet Inter-Orb Protocol (IIOP) are more targeted towards moving information between client-server implementations on potentially different types of platforms. These services provide a stronger platform for developing data sharing systems.

The combination of IP and transport/application services was enough to provide us with the basic tools needed. However, the ability for companies and individuals to rapidly (and effectively) build data/information sharing services relies on a wide variety of application building services (generically called middleware) such as CORBA, JINI, Web Servers, etc. For example, a web server allows any user who can write a simple HTML page (or use a program that knows how to change text and graphics into HTML) to publish the pages for anyone who has a web browser. The user is completely unaware of how information is being managed or distributed. Likewise, the JINI protocol provides an abstract mechanism for registering and locating services of interest (e.g., a color printer in the area, or a correlation service). Similarly CORBA provides a family of services for locating and accessing objects of interest — regardless of where they are located across the network. Finally, XML provides a similar service for organizing and transporting data in a structured and machine neutral format.

These latter tools provide developers (and in some case regular users) with the ability to create sophisticated data/information processing and sharing facilities. Most of these services have been standardized by international or special focus groups and, a result, are available from a wide variety of commercial and free sources.

3 Dreaming The Dream

The development stack described in the previous section promises to provide a very rich programming environment. In an ideal world, these tools allow developers to concentrate on their customer s specific data handling and visualization requirements (a.k.a. mission needs) while relying on the lower layers of the development stack to handle issues such as how to locate or move data between machines.

As usual, there is more than one way to solve the problem of moving and locating data. As a result, a number of competing (and usually incompatible) technologies have evolved (e.g., HTML/CGI Applications, CORBA, DCOM, client-server, etc.) Each of these technologies promises many of the same capabilities (e.g., ability to move, secure and locate data), but often uses a very different model of information sharing. For example, the standard HTML (or web) model assumes that the client asks the server for information. Likewise, they support various types of information distribution — e.g., one-to-one private communication (used for most web activities), one-to-many (such as watching a streaming video of a live event), or even many-to-many (such as a collaborative white-board session). Determining which of these technologies to use is difficult, and most organizations have a new breed of senior developer, often called a technologist, responsible for making the decision.

The ease in which these technologies can be used to rapidly build commercial systems has had a significant impact on the large number of systems that are available today. It has caused a flurry of development focused on not only building the next generation system , but also in wrapping legacy systems so that they can take advantage of many of the new data/information distribution techniques (e.g., adding a web front-end to an existing inventory system.)

In addition to ease of development, the development stack and the standardization process promise us a great amount of flexibility in using different COTS vendors. More recent efforts have resulted in a number of bridges which are intended to allow systems built on different technologies (say CORBA and RMI) to seamlessly interoperate.

Like the commercial environment, the advent of these middleware services has spawned a great deal of interest in DoD, and an unprecedented number of new (and often incompatible) proposals from its contractors.

4 Living The Nightmare

For the past ten years, we have been building middleware-based applications for various DoD organizations such as EUCOM, USA, DISA, and more recently for the Marine Corps Warfighting Lab, and the Extending the Littoral Battlespace ACTD.

Many of these systems have used different middleware technologies, but until recently have been targeted towards larger command and control environments comprised of fairly high end systems connected via state of the art networks. In general, we rarely (if ever) experienced problems with the amount of available network services.

Our recent, and near-term, developments have increasingly focusing on systems where at least a part of the application is connected via a tactical network. Further, they are operating in an environment where the timeliness of information can be either life critical, or have a strong impact on tactical decisions.

While we are strong believers that the use of COTS middleware can indeed provide us with the ability to rapidly develop data/information-sharing systems, our experiences over the past four years have shown that there are many pitfalls to this approach as well.

Many of these lessons were not fully learned until our systems failed to work in the tactical environment. These experiences have led us to adopt a set of approaches to developing and adapting middleware components and protocols supporting the tactical network environment.

4.1 The Tactical Network Environment

There are several important characteristics that differentiate a normal office or laboratory network from a tactical network. In summary these are:

- **Stability** — Normal office networks are comprised of a carefully configured set of routers and cables. An on-site guru is generally responsible for properly configuring and maintaining the connections. The configuration for this type of network does not change very often. A tactical network is often comprised of a mobile communications nodes connected via a variety of RF links. In many instances, we are required to support a zero-footprint network which does not rely only on ANY stable (or pre-existing) nodes. The precise configuration of the network may be created dynamically and change often. The on-site guru s in the tactical environment have other things on their mind, and are not particularly available to reconfigure the network.

- **Connectivity** — Normal office networks are generally well connected to each other. In fact we EXPECT our networks to be connected (if you don t believe me, disconnect your site s connection to the outside world and see how long it takes before the users start to scream — it won t be long.) Tactical networks (particular those that are mobile) have a much lower level of connectivity. The level of connectivity is strongly influenced by RF characteristics (e.g., how the airplane s antenna is pointed while it banks, or EMI interference.) In general, connectivity in a tactical network is either: 1) carefully staged (such as setting up a fixed satellite ground terminal at a good line-of-sight location), or 2) ad-hoc (occasionally network connectivity). The more mobile the resources, the more likely the latter will be true.

- **Throughput** — Basic office networks have at least a T-1 bandwidth. Packet loss rates and packet latency are generally very low (no more than 3% and 250 msec respectively). The resulting network is able to efficiently move information using traditional protocols such as TCP/IP. The throughput on tactical networks can be quite different and is impacted by a number of variables. The characteristics of RF signals and a mobile environment make packet loss much more likely and communications relays may add a significant amount of latency. Together these can severely limit the ability for generic communications protocols to work effectively. Finally, the amount of power available to fielded devices (particularly users who are already carrying packs and weapons) can severely limit the raw bandwidth that can be transmitted.

While many of these problems are similar to those we are starting to see in commercial cellular data-passing networks, the problems are different enough to look elsewhere. In addition to these significant differences, tactical networks must provide an unprecedented amount of security and flexibility in being able to adapt to various tactical needs. For example, the same network may need to dynamically support a large number of local users with a relatively high bandwidth, or a remote set of users via a lower bandwidth.

4.2 Middleware Architectures

As before, over the past few years, we have been involved with teams of developers from other government organizations and industry in building information sharing systems. During this period we have experimented with a number of different middleware architecture and at the same time have been run in an environment comprised of a number of different tactical networks.

In this section, we ll briefly describe each of these systems, its middleware architecture and the tactical network(s) used to connect the users to the system. During each phase, we learned a number of lessons, but have distilled those down into a single lesson we learned concerning how middleware interacts with tactical networks.

4.2.1 Web Portal Architecture

The Urban Warrior experiments took place during the summer of 1998 in the San Francisco Bay area. The intent of these experiments was to evaluate the effectiveness of various techniques and tactics in dealing with conflicts in an Urban Environment. The primary intent of the software system was to provide a Common Tactical Picture (CTP) representing the location of hostile, neutral, and friendly forces as well as allowing users to request actions by others (fires, medical evacuation, resupply, etc.)

As shown in Figure 2, an information-centric decision support system (IMMACCS) was designed to support the information collaboration needs of the exercise. By intent, all IMMACCS components would communicate and exchange information solely via a common object model. A CORBA-based middleware system (Shared Net) was deployed aboard the USS Coronado. The Shared Net used the IMMACCS object model, with its rich associations, to provide an information-centric representation of the battlespace. Shared Net used a standard publish-subscribe model to distribute objects of interest to specific clients. IMMACCS Translators (MCSIT) were used to interface between existing military systems (GCCS, LAWS, & TSCM) that normally communicated via message-oriented protocols and the objectified forms used by the Shared Net. Unfortunately, due to personnel problems, earlier efforts to build an IMMACCS object model aware client had failed. Instead, users (both aboard ship in San Francisco, and those fielded in Oakland) were provided with a web browser, and used a web portal to access tactical information (such as location of enemy and friendly units as well as medical evacuation requests) maintained in the Shared Net. In effect, the web portal receives a service requests (via HTTP) from a small application running on top of the client s web browser, the web server responds to the request by making an appropriate call to the underlying information service (in this case Shared Net). The web server then takes the information returned by the information service, and re-encodes it (often in HTML) and sends it to the client s web browser via HTTP.

In a portal architecture, the user s client is generally nothing more than a COTS web browser augmented with a few (usually small) Java applets. The majority of the processing needed is done by the web server (and its associated processes) is related to: 1) taking the information request provided by the client and converting it into a request that the underlying information store(s) can understand (e.g., converting to SQL), and 2) taking the information provided by the store(s) and converting it into a format that can be either directly displayed on a web browser, or one that can be interpreted by the client s Java applets.

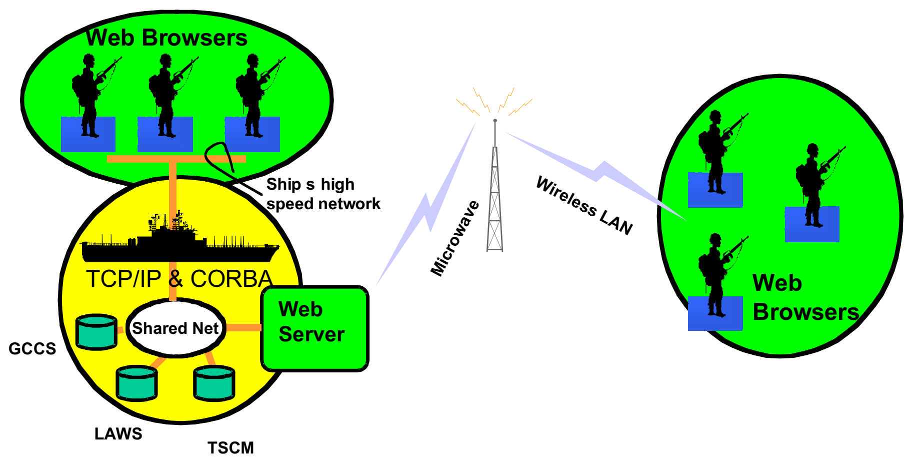

Figure 2. IMMACCS over INITS

The Urban Warrior exercise used a two-tier network (called INITS). The long haul was comprised of a multi-hop microwave link. Communications between the microwave tower and the fielded users was via a commercial wireless Ethernet (using the 802.11 protocol). Microwave relays were generally pre-positioned in areas that would provide good connectivity to the ship. Amazingly enough, this involved shooting a signal from San Francisco to Oakland which passed between the top of San Francisco Bay and the bottom of the Oakland Bay Bridge.

Performance

The performance of the web portal architecture during the exercise was mixed. Users who were aboard ship were generally able to share information effectively. However, fielded users in Oakland rarely saw the same common picture as their counterparts aboard ship. In addition, the ship received very little position or tactical data from the fielded users. Overall, the system s ability to support the goal of the exercise (users fielded in an Urban environment) was poor. In trying to understand the poor performance, we looked at two components: the network and the web portal (the other components appeared to be working well and were not examined further.)

As before, shipboard clients worked well, but fielded clients did not. The primary difference between these users was the type of network used to connect them to the web portal. As is typical for software developers, we initially thought that the problem was in the network. However, other systems (such as a live streaming video feed and the standard network news protocol) were able to run across the same (INITS) network with little or no problem.

Reviewing the web portal, we discovered that the portal had crashed a number of times and needed to be restarted. While not of significance in itself, it was worth examining and helped us in further evaluating the middleware architecture.

Its important to note that both the web portal and the INITS network performed well in independent testing. However, something in the interaction between these two systems resulted in the poor field results.

One possible problem was primarily related to the system s scalability. The web portal approach uses a web-standard request-reply communication model — in effect it is a private one-to-one communication between the client and the server. However, a CTP requires that all users receive approximately the same set of information so it is more akin to the one-to-many communication model. Under the one-to-one model, a single position update by a fielded user would result in each client downloading the new information. While not a problem with small numbers of users, it could be a problem with larger numbers. Combined with the slightly lower bandwidth of the INITS network, this could have been enough to cause the servers to time out on the client s request.

<u>Lesson Learned:</u>
While COTS middleware can help in rapidly building distributed systems, COTS approaches work well only <u>if</u> the information distribution model they provide meets your needs.

4.2.2 CORBA Client-Server Architecture

The IMMACCS system (described previously) continued to evolve. Based on our Urban Warrior experience, we made two significant changes:

1. An IMMACCS Object Model aware client was developed in Java.
2. Modifications were made to the Shared Net s information distribution services to enable it to handle a larger number of clients. Additionally, a service (similar to the CORBA event service) was provided that distributed only the part of objects that had changed (rather than the whole object).

In effect the COTS CORBA middleware approach used by the Shared Net to communicate with the other IMMACCS servers (translators, agents, etc.) was extended to communicate with the Java clients. Together they replaced the web portal middleware approach with a client-server approach.

Additionally, a tactical network being developed as part of the Extending the Littoral Battlespace (ELB) ACTD replaced the INITS network. The ELB network, called Warnet uses a novel 3-tier approach combining VRC-99, TCDL, NTDR, and wireless 802.11 links. Warnet nodes are mounted on HMMWVs, fixed wing aircraft, rotary aircraft, and ships. Users are equipped with 802.11 cards that connect them to the nearest Warnet node. Communication between the nodes is time-division-multiplexed and the number of slots assigned to communication between any two nodes can be configured to support the required bandwidth. Warnet also has the ability to broadcast in a one-to-many mode that enables all nodes to receive the same packet without requiring it to be individually broadcast to each node. Warnet represents a self-configuring network where the nodes are continuously entering and leaving the network.

The combined system (shown in Figure 3) was field tested as part of ELB s Full System Test (FST-2) in Gulf Port, MI during August of 2000. This was the first time the systems had been run together.

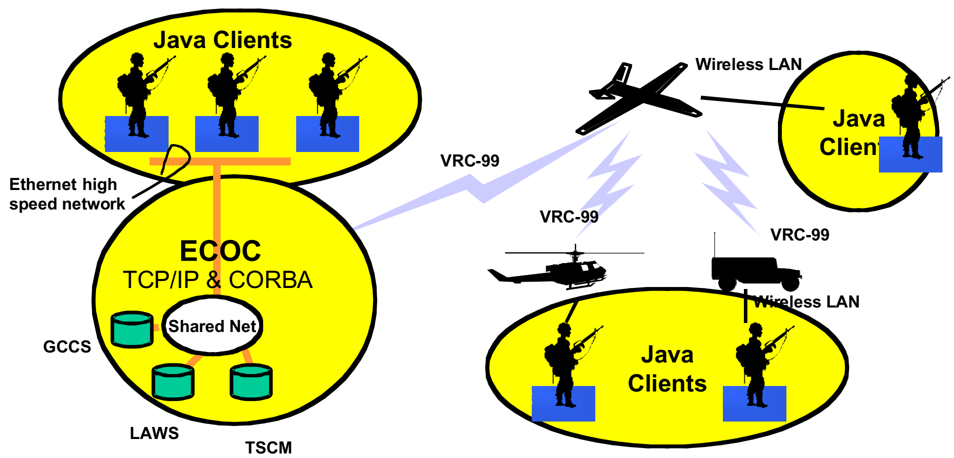

Figure 3. IMMACCS over Warnet

The goal of FST-2 was to show that we could provide a CTP to mobile users distributed over a reasonably small tactical area (10s of miles). Due to scheduling conflicts, the command center was moved from the ship to the shore.

Performance

The performance of the COTS CORBA architecture used by Shared Net during the exercise was mixed. ECOC users, connected via a traditional Ethernet, were generally able to share information effectively. However, fielded users connected via Warnet rarely saw a CTP. In fact, two fielded users connected to the same communication node (and often standing right next to each other) didn t see the same picture. In some cases, one fielded user would see 10 tracks, and his buddy would see more than 200. In some instances, a fielded client would take as long as 45 minutes to fully populate tracks. Again, the operational goal of the system was not met.

As before, we tried to understand the interaction between the middleware and the network. This was greatly complicated by the fact that both were experimental and significant changes had recently been made. A few clues helped our investigation:

- Starting up clients one at a time (rather than all at once) seemed to help. This pointed us towards a resource (network or server) utilization issue.
- Clients were still able to use news clients to connect to the ECOC, but had difficulty in using newer applications such as web browsers.
- Network tools indicated that IP receive window was often frozen — generally indicating that the receiver is has still not received a missing packet even after it has requested its retransmission several times. This could have been caused by either the network dropping a lot of packets, or the application layer trying to send too many.

As before, the problem was not in solely in either the network, or the software, but in the complex interaction between the two. While INITS was reasonably similar to a wired Ethernet, Warnet displayed most of the characteristics we would expect to see in a true tactical network. Packet loss was high (~ 30%), and latencies were long (~3 seconds). Further the extremely damp weather, constantly mobile nodes, and not infrequent lightning strikes resulted in very short duration communication windows (routers do <u>not</u> respond well to being hit by lightning.) While improvements could certainly be made to Warnet (and were), it was a reasonable representation of a tactical network.

Unfortunately, the COTS middleware software had been developed to support *enterprise* computing over traditional networks. As such it made heavy use of the TCP/IP protocol. *This was the crux of the problem*. The long latencies and relatively large packet loss rates exhibited by Warnet were well outside the performance parameters of TCP/IP which exhibits incredibly poor performance if the latency exceeds 300 msec or the packet loss rates exceed 8%. In both cases we were well in excess of those values. The result is that TCP/IP traffic simply did not get through the Warnet network. The more traffic we tried to send (say retransmits of missed messages, or new clients starting up and trying to retrieve objects) the worse the communications became.

Perversely enough, the network statistics showed that the network was performing well. Unfortunately, the network statistic was based on bandwidth — how many bits cross the network regardless of what they represent. From a software perspective we are interested in throughput — a measure of whether the packets we send from one application successfully reach the other application. Thus while the bandwidth was high, the throughput was very low.

<u>Lesson Learned:</u>
While COTS middleware can help in rapidly building distributed systems, COTS approaches work well only if the environment they are intended to support (e.g., communications, host processors, etc.) is VERY similar to the deployment environment.

4.2.3 Adapted CORBA Client-Server Architecture

Based on the lessons learned from FST-2, both Warnet and the middleware component of Shared Net evolved. Warnet continued to reduce packet loss and latency, and added new algorithms to better handle flow control and efficiently support broadcast protocols (such as multicast). The Shared Net s middleware components also exhibited significant change:

- Approximately 95% of the routines that used TCP/IP were rewritten to use Multicast. Only direct CORBA set and get methods were left using TCP/IP.
- The Multicast layer was tailored to meet the parameters of the Warnet. This included automatically broadcasting each packet again after a fixed amount of time.
- Middleware services were modified to implement a timed store-and-forward service where information destined for unreachable nodes is queued (for a bounded time), and delivered when communications was available.
- The middleware client-stubs were substantially rewritten to mimic a write-through cache. In general, all client read operations are served by a local object cache, an update service is then used to ensure that the distributed cache is synchronized between all clients and servers.

The resulting architecture is virtually identical to that shown in Figure 3. In fact, one of the advantages of the middleware approach is that the implementation of the middleware components can be substantially changed (say by replacing TCP/IP with Multicast in 3 months) without requiring changes to be made to servers or clients using the Shared Net middleware.

The resulting modified architecture was fielded during FST-3 that took place at Camp Pendleton (near Oceanside, CA) during March 2001.

Performance

The performance of the modified COTS CORBA architecture used by Shared Net over Warnet was significantly better and generally usable. ECOC users, connected via a traditional Ethernet, retained their virtually identical CTP. However for the first time, fielded users, connected via Warnet, also saw a relatively common CTP.

However, the CTP for fielded users wasn t perfect and tended to become less common as network communications became less reliable. COTS CORBA requests issued by the clients (sets and gets) were not able to get through during marginal communications. Similarly, when communications were re-established, each client requested retransmission of the multicast traffic it had missed and tried to resubmit CORBA calls that had failed. While the multicast rebroadcast approach helped to satisfy multiple client s needs with a single broadcast, the overall traffic on the Warnet was unacceptably high and reportedly could cause the network to go into flow control mode.

This pointed out three significant issues for a tactical architecture:

- Since each client acts independently, there is generally no mechanism to limit the impact that a rogue (or even greedy or starved) client can have on the network.
- In mobile topologies, at some time or another the server is at the far end of the network, and the clients needing the information most are at the other. This

happened more often that we would have expected and has a significant impact on the network.

- Having only a single server connected via a network that provides only occasional connectivity can significantly frustrate users who are used to working on a highly connected network. While this rightly falls in the no-duh category of obvious problems, it still hit us. We finally had to take away options that allowed users to refresh their screen by re-retrieving all of the information.

Lesson Learned:

While COTS middleware can help in rapidly building distributed systems, COTS approaches work well only if the network connectivity the COTS product is intended to support is similar to the one in your deployment environment.

While this seems relatively obvious, its important to realize that most commercial software is not intended to support long (say > 30 second) communications outages. In most cases, the connections are dropped and the user is expected to reconnect at a later time. Blame is generally focused on the network service provider, since we are prepossessed to expect a perfect network.

4.2.4 Distributed Middleware Servers

The final version of the Shared Net middleware is currently being field tested running over both INITS and Warnet in preparation for ELB s Major Systems Demonstration #2, and the Marine Corps Capable Warrior exercises both occurring in the South West states during June 2001.

The most significant change to the architecture has been in installing lite (NT laptop) versions of the Shared Net middleware servers in the majority of Warnet s communications nodes. In effect, there are now Shared Net nodes in HWMMVs, fixed wing aircraft, helicopters, and potentially LCACs. A total of 11 Shared Net servers will be used to support the upcoming exercises.

Each Shared Net node is able to support a number of clients in the same way that the single server did. However, in this architecture, Shared Net nodes are also clients to other Shared Net nodes. In effect the distributed Shared Net servers implement a loose but ordered, quorum. The information available on a server is at least as good as the client could have received by itself, and in most cases is significantly better.

This approach has a number of advantages, particularly in a tactical arena where communications outages will likely be common, and an accurate and timely local tactical picture is more important that a less timely (or accurate) regional picture:

- The clients are more likely to be able to communicate with the local communication node s server than with a remote server.
- The local server effectively maintains the local Common Tactical Picture to its local clients. It selectively shares this picture with other servers, and in turn receives updates from them, as communications bandwidth is available.

- Each server acts as a reliable store-and-forward service, once it receives a change from a client, it is the local Shared Net server s job to ensure its delivery it to all other *interested*[2] servers.
- The vast majority of traffic across the Warnet (or any haul network links) is now comprised of server-to-server updates rather than client-server communications.

Performance

In mobile field tests held during the past month, the distributed architecture appears to be meshing well with the tactical network. The test involved a command center aboard the USS Coronado docked in San Diego, multiple maneuvering Marine units (in both STOM and RSTA configurations) at Camp Pendleton, and RSTA units in El Centro, CA and Yuma, AZ. Each location was connected via Warnet; in some cases this required using multiple airborne relay hops.

The clients associated with each local server shared an identical local (or relevant) Common Tactical Picture. They also received updates from other servers when communications were available (in some situations, connectivity was only provided for minutes each hour).

Lesson Learned:

When its properly modified and selected, COTS middleware can support the information sharing needed to maintain a Common Relevant Tactical Picture across tactical networks.

5 Learning From the Past

While we learned a number of valuable lessons during this process, we have always been aware of the fact that news was almost always able to run across the tactical networks when our more advanced and capable systems could not. During some of the exercises news was virtually the only reliable way of moving information between commands, and the users moved significant amounts of information (in the form of spreadsheets, images, and documents) between each other by attaching them to news postings. Why then could this rather old product operate when we could not?

News ability to function in this environment is largely due to the environment in which the Network News Transport Protocol (NNTP), used to exchange news postings across networks, was developed. NNTP was initially developed at a time when machines were very loosely connected by modems and dial-up connections. NNTP servers would occasionally dial-up another NNTP and share postings in selected news groups with each other. Connections were generally bad, and it was not unusual for the connection to break before the exchange was complete. As such NNTP provides the ability for servers to reconnect and resume the state of their last connection.

In many ways, the characteristics of the network connections NNTP was developed to support are very similar to those we experience in tactical networks today. From a

[2] In our architecture, we assume that not all servers will share all information. For example, servers could be configured to share particular types of information within either geographic or echelon boundaries.

modern architecture point — NNTP may be rather sophisticated. In modern terms, NNTP implements a store-and-forward distributed server architecture that uses local caching and opportunistic subscription-based exchange. Interestingly enough, a significant subset of the same approaches that Shared Net eventually evolved to use.

So why aren t our COTS components as resilient as our older approaches? There are two possible scenarios:

1. There is little market force for this type of reliability. This seems rather unlikely since commercial organizations are spending a significant amount of money to make their systems fault tolerant.

2. Our COTS components (and our own developers in general) assume a fairly high level of service from the underlying networks and protocols. As time pressure to develop software has increased, we ve moved our resources to implementing applications layered upon these services and give little though to how they will react under different network situations.

The latter is not only likely, but it may be completely appropriate for COTS. It is important to realize that COTS is a market driven commodity. As such it is highly unlikely that a COTS manufacturer would invest the effort necessary to make their software tolerant of faults (or behaviors) that occur only on networks that are NOT used by any significant percentage of their market share. In any event, a customer suitably motivated to use a particular COTS middleware program will likely be willing to pay for customization, either by their own staff or the vendor.

6 Communications Services for Tactical Networks

Undoubtedly, COTS middleware can provide us with significantly enhanced capabilities to build information sharing systems. However, as we ve seen in the previous examples, out-of-the-box COTS, may be insufficient to meet our needs — particularly if we extend our information sharing systems across tactical networks.

It is essential that we don t merely tune our systems to a target network. Like our software systems, networks are evolving at a rapid pace. Its unlikely that the network we use today will be the same as the ones the system will run on 5 years from now. Rather, we need to provide a generic set of communications services (either under or within our middleware layers) that will allow an integrator to configure the system to support the particular needs of their users and capabilities of their network(s).

Our experience with Shared Net has shown us that we can use 85% or more of the out-of-the-box COTS software services (for example, we can use persistence, but need to modify CORBA event services). The portion that needs to be modified is generally focused on lower level communications routines used by many of the higher level services. In order to maximize our portability (and ability to use any future COTS or

GOTS implementation that evolve to meet our tactical communications needs) we need to implement our changes within the structure of middleware standards. For example, if the specification of the CORBA event service meets our architectural needs, but the implementation will not run on a tactical network, then we need to re-implement the event service to give it greater capabilities, not write an entirely different service which would be unique to our system.

Based on our lessons learned, these communication services need to have the following properties:

Efficient & Transparent Encoding of Information.

In many tactical networks, packet size must be small. It is important that we maximize the use of the network resource. However, at the application layer, the ability to share information between systems is largely based on more greedy forms. For example, XML provides a widely accepted interchange format that is easily read by other programs. Unfortunately, it is based on tagged ASCII text, which is hardly an efficient representation of numeric data. The communications layer should allow the applications to use these verbose forms, but should convert the information into a network-suitable form (encoding and packet size) before it transits the network, and transparently convert it back when it reaches the appropriate level on the other side.

Error Correction and Recovery

The reliability of our commercial networks, and the low cost of simply detecting (say thru checksums) and retransmitting corrupted packets have made the use of error correcting approaches less appealing. However, in instances were the networks are less reliable or retransmission imposes a significant time lag and/or excessive use of resources, error corrections and recover approaches can provide a significant enhancement network throughput. While these approaches increase the amount of information that needs to pass over the network, in many cases they will allow a damaged packet to be recovered thus avoiding the cost of retransmitting the packet again and allowing the information to be used more quickly.

Quality of Service Indicators

Not all information has the same delivery requirements. In some cases, critical information MUST be delivered as quickly as possible. In others, information might be delivered using a best-effort approach where the information is dropped if it can be delivered after a number of tries or may be queued for delivery until higher priority traffic has been delivered. Likewise, many type of information have a lifespan after which it is useless and can be discarded. Finally, certain types of information may be replaced — i.e., updates that supercede earlier updates should replace them rather than using the resources to transmit the original followed by the change. This service is not without dangers. Many systems using this service may be built upon belief of how network protocols such as TCP provide data (say totally ordered and complete). As such, the application layer should indicate the quality of service it needs, and the communications layer should attempt to provide it or signal the reason why it cannot.

Efficient Transport/Confirmation

Standard IP protocols provide for either an acknowledgement for every message received (TCP) or no acknowledgements at all (UDP). The former uses a significant amount of bandwidth, and the later leaves responsibility for reliable and ordered deliver to the application layer. Neither are acceptable solutions for our tactical network. Commercial IP stack vendors are beginning to experiment with more optimistic acknowledgement approaches (such as negative acknowledgements, summary acknowledgements, and piggy-backing acknowledgements on regular outbound traffic.) The communications layer should utilize or offer these services to optimize reliable transport across the network. Additionally, it may be beneficial to adaptively and pre-emptively retransmit packets that our monitoring systems or recent history lead us to believe will not be received.

Independence of the Distribution and Communications Models.

In many commercial applications, the distribution model (one-to-one, one-to-many, or many-to-many) tends to dictate the communication model (unicast, multicast, etc.) As our experience has shown, some networks may not be amenable to certain communication models (as Warnet was not amenable to TCP). Unfortunately, in Shared Net the communication and distribution models were tightly coupled. By giving up TCP, we needlessly gave up the ability to give tailored information feeds to individual clients. This caused a significant loss of capabilities and was an extremely inefficient use of bandwidth. The communications layer should be wholly independent of the distribution model.

Support for Partial Ordering of Events.

Communication protocols, like UDP, do not guarantee that packets will be delivered to the application in the same order they were delivered. Further, using the Quality of Service Indicator means that under certain conditions, packets should not be delivered at all. In total ordering systems, packets are only delivered to the application if all previous packets have already been sent up. This can result in sever time delays especially if the retransmission delay is long. Often, this is mitigated by waiting a maximum amount of time before giving up on the packet and processing the rest that are behind it. The total ordering requirement is often unnecessarily strict. In most of our systems, a more relaxed, or partial ordering, of events would be entirely sufficient. For example, its important that a create event on object A is processed before an modify event on the same object. However, the order in which I process create events on objects B and C is unimportant. If the create event on object A is not delivered, then we must suspend processing of the modify on object A. However, we are completely free to process the create events on objects B & C.

7 Living The Dream

The promise of building distributed information sharing systems using COTS middleware components is alive and bright. Our experience over the past four years has shown that many of these components and approaches can be directly used in the tactical environment.

However, tactical networks provide a level of service that currently is significantly different from that offered by commercial wired networks familiar to most developers. As a result, portions of these middleware products do not perform well on tactical networks, and must be adapted before they can be used.

The significant evolution that has taken place in the Shared Net application over the past three years could not have been accomplished with our small team without middleware. The fact that these significant changes were made within minor or no impact on the clients is a strong endorsement middleware ability to provide a service-based architecture.

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Will We Ever Achieve a Network Centric Navy? DoD Acquisition System Adjustments and Reforms Necessary to Bring About the Successful Migration

Scot A. Miller
Captain, United States Navy

Student, Advanced Research Program
Naval War College, Newport, Rhode Island

Abstract

Information Age technology offers empowering opportunities to the organizations that can best take advantage of them. The Navy introduced network centric warfare as their Information Age concept. Unfortunately, the current acquisition system strangles initiative and precludes motivated Naval personnel from initiating network centric operations in the fleet. Further, this acquisition system will not permit the procurement of the more technically challenging network centric components needed for a true long term network centric force.

Analyzing the five tenets of the network centric warfare concept reveals tangible end items needed to grow a network centric force. The results of those analyses suggest these requirements separate into two groups: essential hardware and software acquirable in the near term by adjusting the current acquisition system; and advanced networks and platforms available only after fundamental change to the acquisition process. This paper indicates these short term adjustments will launch rudimentary network centric operations in the Navy while the necessary long term reforms will make possible the envisioned future network centric force.

Keywords

network centric warfare; DoD acquisition process; joint requirements; military innovation; program management.

Introduction

The Information Age is rapidly permeating the existing Industrial Age business and social infrastructure. Shifts in the evolution of work offer considerable opportunity to those who change effectively. The Navy recognizes this opportunity and has responded with a broadly defined concept known as network centric warfare, designed to capitalize on those novel technologies. Proponents predict network centric warfare will qualitatively improve the Navy, allowing it to meet its commitments without significant funding increases. However, change involves risk. Most observers agree that adopting network centric warfare concepts will cause significant and long lasting change to the Navy. Critics deride the notion of "Lifting the Fog of War", (Owens, 2000) as Admiral Bill Owens puts it. Marine Colonel T. X. Hammes argues that network centric warfare will not survive the first salvo (Hammes 1998). The happy news is that this tension is healthy and will ensure that network centric warfare will meet the nation's needs.

Unfortunately, the current acquisition system stifles innovation and prevents fiscal flexibility. Moreover, the longer term outlook for acquiring the true revolutionary network centric warfare tools is worse. The platform centric acquisition process will not support the needed procurement for a network centric Naval force. Parochialism, both platform and service oriented, is a sturdy roadblock to necessary enlightened thinking. Congress oversees DoD spending "in an episodic, erratic manner. (Hamilton 1999)"

Perspective

The Navy already owns the resources who can start network centric warfare in the Fleet; its people. Daily, hundreds of sailors, Marines, and Navy civilians use networks attempt to institute innovative new ways to execute operations more efficiently and effectively, but are most often thwarted. Numerous examples illustrate this daily frustration.

Shipboard configuration control requires testing nominated software, but the configuration control authority has insufficient funds to test all potential software introductions. Yet the software provider is not allowed to pay for the testing either, so a Fleet need goes unfilled (Patterson 2001).

Another example is the Navy's inability to translate an unexpected winning idea into an organized and supported program. A program known as Collaboration at Sea (CaS) first deployed in the USS John C. Stennis battle group in January 2000. Increased battle group situational awareness, reduced routine message traffic, and improved battle group collaboration resulted. Consequently CaS was installed on all subsequent deploying battle groups. Nevertheless, CaS could provide considerably more network-based capability for the warfighters if not for the lack of an official program sponsor or integrated support infrastructure.

There is precedence for progress. After World War I the Navy developed a new way of naval warfare based on carrier aviation, despite limited funding. The keys were open debate, rapid establishment of a supporting bureaucracy, and experimentation and concept development. Most importantly, the dialogue between Naval War College, the Washington Navy bureaus, and the fleet was nearly continuous.

How can the Navy grow a network centric force with this intractable acquisition process? This paper bridges the gap between the high brow concepts of network centric warfare and the hardscrabble realities of the current acquisition process by using a three step process:
1) understand the network centric warfare concepts and equate those concepts to operationally relevant examples; 2) analyze those examples and find tangible requirements and their associated characteristics needed to achieve a network centric force; and 3) determine potential strategies for achieving the necessary adjustments and reforms necessary to move towards a Navy network centric force. The process result is a potential way ahead to both kick start network centric operations today and achieve the advanced network centric warfare force of the future.

Understanding Network Centric Warfare

The Naval Warfare Development Command is responsible for concept development in the Navy. They define network centric warfare with five tenets (see figure 1) (Martoglio 2000).

In the complete paper an operational example is designed to examine Naval force employment across a broad spectrum of warfare challenges, from peace operations to conventional warfare. This translation into an operational example brings clarity to what many argue is just wishful thinking. For the sake of brevity, analyzing the operational example generates the following requirements, as noted in figure 2.

NWDC Network Centric Warfare Concepts

1. Know the adversary
2. Establish situational awareness
3. Iteratively create commanders intent
4. Decentralized execution
5. Self synchronization

Figure 1: NWDC Network Centric Warfare Tenets

NETWORK CENTRIC WARFARE EQUIPMENT REQUIREMENTS	
NEAR TERM (modify current acquisition process)	**LONG TERM** (reform acquisition process)
Internet Protocol Based Force Coordination and Planning Network	Widespread Force Control Network
Knowledge Sharing Infrastructure	Deployable Micro Sensor Grids
Visualization and Awareness Tools	Unmanned Combat Vehicles
	Engagement Grids

Figure 2: Representative Network Centric Warfare Equipment Requirements

When these requirements are analyzed, they split into two broad categories: capabilities acquirable by using the existing acquisition system; and the technically and doctrinally challenging items, that can only be acquired after reforms of the current acquisition system.

Adjusting the Current Acquisition System

Obstructions experienced daily that are attributable to the current acquisition system include the inflexibility of the system to move money, the disastrous side effects of well intentioned rules, and the lack of structure and support for innovative ideas. These obstructions slow acquisition of the identified near term requirements and stifle innovation. Several modifications to the acquisition process can assist making the Navy network centric today.

First, realizing the existing and future benefits that the current acquisition process provides is important. These benefits are found in the realm of program management. From the integrated product teams, which first put together a program, to the lifecycle functions that nourish programs, the program manager and his or her team provide a plethora of services that sustain specific programs. Program managers support programs by identifying and supplying required maintenance, manpower, supply support, training and associated training devices, and support equipment. Program managers actively seek improvements to their programs during its lifecycle, and when a program reaches the end of service, ensure that disposal requirements mandated by law are satisfied. Program managers and their staffs are acquisition professionals; most are highly trained and experienced in their fields of expertise.

Just as in industry, the fleet operators, day in and day out, observe ways to improve operational processes. Capitalizing on the immense pool of intellect in the fleet can rapidly improve the use of the new technologically advanced tools and move the Navy forward towards networked operations.

For such an idea to succeed, it needs four components: 1) an operational advocate who can push the opportunity; 2) an organization that ensures associated education and training are given to all fleet users; 3) a systems command to provide program office support for installations, logistics support, and manuals; and 4) a program sponsor to provide necessary funding. The Rapid Prototyping Cell at Naval Air and Strike Warfare Center meet these requirements, and has succeeded or is in the middle of migrating ten fleet generated ideas to the entire fleet(Wilke 2001). This idea should be tried at other primary warfare centers.

This approach can be more successful if program sponsors were given more leeway in how they apportioned their money. Extending a model started in the Army several years ago, known as the Warfighting Rapid Acquisition Program (WRAP), offers one way of greatly increasing the flexibility and spending discretion of the CNO's program sponsors. For fiscal year 1998, the Department of the Army set aside \$100 million for accelerating the "procurement of systems identified through warfighting experiments as compelling successes that satisfy urgent needs (Department of the Army, 1999)." The Chief of Staff of the Army himself approved disbursement of the monies. The purpose of the fund was to support rapid prototyping of promising technologies emerging from any of the nine Army battle laboratories. Response time for funding requests was 30 days maximum.

If program sponsors on the CNO's staff had access to money of this magnitude, it would greatly increase their flexibility. For example, CaS rapidly gained high level support, but remains burdened with unsupplied promise. If a program sponsor could have responded within 30 days with the approximately $3 million needed to properly execute the CaS program, the Navy would already be reaping the additional potential benefits CaS offers.

The unintended negative consequences of bureaucratic rules continue to plague innovation. Reinstitute the 1994 DoD rule which states:

> *Waiver-of-regulations requests must be acted upon within 30 days. After 30 days, if no answer is forthcoming, the party asking for the waiver can* ***assume approval*** *and implement the waiver. Those officials with the authority to change regulations can approve waiver requests, but* ***only*** *the head of the agency can deny a request* (Collins 1999).

These adjustments can make a credible difference in starting network centric operations in the Navy. Give sailors a chance to be innovative, and there is no end to what may be accomplished, even before the high technology tools promised in the future become available.

Reforming the Acquisition Process to Complete the Network Centric Warfare Dream

Gaining the new tools of network centric warfare requires structural change in the current acquisition system. The acquisition system must change the mindset of the participants from an Industrial Age focus on platforms to an Information Age focus on networks. The networks will be the drivers of network centric success; platforms, sensors, weapons, and personnel must plug in and use the network to best tactical and operational advantage.

Admiral Owens suggest a small cadre that produces joint requirements and budgets the Department of Defense (DoD) resource allocation according to those requirements (Owens 2000). The Special Operations Command already conducts joint requirements generation and budgeting for all the services' special forces. The Swedish Armed Forces use a cadre of less than 100 people to do the same for their armed forces (Gustafsson 2001). Owens' idea requires Congressional action to change the meaning and definition of Title X in the United States Code.

Moreover, Congress must pass legislation regulating its own role in DoD oversight. They must focus their oversight on ensuring the DoD is moving towards an Information Age force, an added responsibility. However, they must also agree to eliminate the duplicative and conflicting oversight by which they now subject the DoD. This can be accomplished by: 1) establishing one DoD organization which serves as Congress' single point of contact with DoD; 2) institute an electronic tracking system for Congressional information requests; 3) agree upon recurring reports and procedures which minimize unscheduled requests (Scott 1995); and

4) require Congress to establish a cost benefit measure for oversight and report that measure publicly twice a year.

Final Thoughts

Network centric warfare is not just about buying new technology, but smartly and effectively employing that technology in new and innovative ways. Adjusting the current acquisition process will enable the Navy to start network centric operations today, setting the foundation for the new and revolutionary tools to follow. The transition from the present platform centric force to the fully netted force of the future also requires a carefully considered migration plan. This means change management. Finally, modifications and reforms to the acquisition process will help the Navy achieve network centric warfare, but not all by itself. Changes to our education and training process, forward thinking leadership, and the rapid development of tactics, techniques, procedures, and doctrine will share the forefront.

References

Collins, J. "Turning Goals into Results: The Power of Catalytic Mechanisms," *Harvard Business Review*, July-August 1999, pp. 71-3.

Department of the Army, Training and Doctrine Command, TRADOC Pamphlet 71-9, November 5, 1999, section 13-10.

Gustafsson, S. Lieutenant Colonel, Swedish Armed Forces, interview by author, May 24, 2001.

Hamilton, L.H. "Oversight: A Key Congressional Function" (remarks presented to the Congressional Oversight Workshop, June 28, 1999).

Hammes, T.X. "War Isn't a Rational Business," *U.S. Naval Institute Proceedings*, July 1998, p. 23.

Martoglio, C. M. "Network Centric Operations." Description used by Naval Warfare Development Command, Newport, RI, 2000, pp. 1-5.

Owens, W. *Lifting the Fog of War* (New York: Farrar, Straw, and Giroux, 2000), pp. 150-354.

Patterson, S. <patterson@spawar.navy.mil>, "Cache Flow" [E-mail to Bob Younger <younger@spawar.navy.mil>], March 30, 2001.

Scott, W.F., et al. "Project Kaizen Looks at Congressional Oversight of Defense Acquisition Programs," *Acquisition Review Quarterly*, Winter 1995, p. 87.

Wilke, R. Director, Naval Strike and Air Warfare Command Rapid Prototyping Cell, telephone conversation with author, May 22, 2000.

As the Revolution Continues: We need Integrated Technological Solutions to Complex Department of Defense Logistics Problems

Chris K. Neff
Logistics Program Analyst
U.S. Pacific Fleet, Pearl Harbor, Hi 96860

Abstract

A changing geo-political environment, growing reliance on economies beyond our borders, and requirements for U.S. presence in remote locations; place increased demands on logistics systems and networks to provide the right material, to the right location at the right time while supporting an ever changing mission. The U.S. Government s lengthy and complex resourcing process, combined with the numerous stovepipe organizational relationships, makes it difficult to obtain the material, and personnel required to meet the challenges of this highly dynamic environment. The current desire for varied and more detailed information will require a responsive partnership of organizations and the effective integration of data, information, and decision makers. Failure to utilize modern information management techniques and capabilities will yield sub-optimized decisions, wasted resources, and unsatisfactory results.

Keywords

Sub-optimized, decision support, logistics network, transportation, inventory management, just-in-time, financial management

Disclaimer

The views expressed in this discussion do not necessarily represent the official position of the U.S. Navy, or the Commander in Chief, U.S. Pacific Fleet.

Introduction

Modern military actions require the effective management of assigned assets, and the ability to obtain adequate resources to operate and maintain them. The Federal Government s Planning, Programming, Budgeting System (PPBS) process, requires the Department of Defense (DOD) to submit annual budget requests to the President approximately eighteen months prior to the start of the fiscal year the funds are needed. Budget requests cover a five year period, the Five Year Defense Program (FYDP), placing demands on agencies to predict future year funding years up to thirty months in advance of actual resource spending. Challenges exist when service agencies must predict: global threats, platforms or force structure (ship, aircraft) to counter these threats, personnel (grade level, skill set, replacement) to support execution plans, research & development initiatives to meet out year threats, and annual facility and unit operations and maintenance resources. Within the Department of the Navy (DON) this effort requires a complex balance of future capability with the need to go *Forward From the Sea* anytime, anywhere. Historically, prior execution has been the basis for projecting future requirements however, significant benefit would be derived if better predictive models were available, and assisted support systems were developed to bring together the numerous disparate legacy information management systems in order to provide accountable personnel with the knowledge needed to make better decisions.

The Challenge of Change

The security environment in which we live is dynamic and uncertain, replete with a host of threats and challenges that have the potential to grow more deadly.
President Clinton, National Security Strategy, 1999

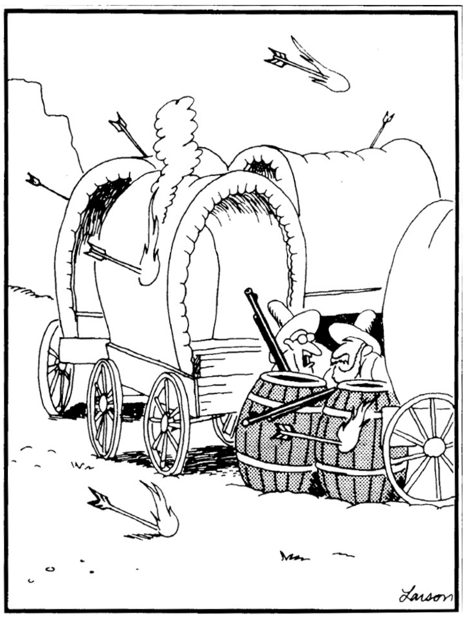
The demise of the *Cold War* has resulted in the development of strategic plans which are based on the assumption that there will be no Naval peer competitor for the next two decades. There is a recognition that in order to ensure regional stability the Navy will need to maintain a forward presence in the Middle East, Asia, Europe, and the Americas. The threat will include the transfer of technologically advanced weapons and sensor systems as well as nuclear, biological, and chemical weapons to aggressor states.

In order to prepare for the future, the impacts of fiscal restraint of our adversaries, our allied or coalition forces, and ourselves can not be downplayed. As an example the costs associated with building, operating, and maintaining modern nuclear submarines while maintaining a stealth-like operational signature results in foreign powers constructing conventional submarines in order to provide this important capability. This threat has been a major concern to maritime nations since World War II. During RIMPAC 2000, a major fleet exercise that takes place every other year with nations around the Pacific rim, the Royal Australian Navy s (RAN) *Collins Class* submarine demonstrated such a capability, highlighting the importance of working with our allies and friends in order to ensure global challenges are met with a balanced and coordinated concept of operations, and training regime.

The U.S. Navy must continue to dominate the maritime environment to dissuade regional powers from aggressive actions, and be prepared to engage in a full spectrum of Military Operations Other than War (MOOTW). Recent global events highlight the Navy s role in humanitarian disaster relief, non-combatant evacuation operations (NEO), peace support missions, enforcement of embargoes and no-fly zones, drug interdiction, illegal immigration, international criminal activity, and rapid response to terrorism.

In order to meet the challenge of change we must be able to sustain a long-term, forward deployed presence. Within the Pacific Fleet this can mean supporting our deployed forces through the discipline of sea-based logistics with a full spectrum of battle force replenishment, operational logistics, weapons handling, force support, maintenance, and infrastructure from logistics bases over 14,000 NM away. These disciplines include the challenges of: conducting re-supply in sea state 3 conditions, Total Asset Visibility, providing logistics information to operators, safe knowledgeable weapons handling, anti-fouling coatings and deck coverings, transportation, re-supply and predictive maintenance actions. (Natter, 2000)

With this background of dynamic and asymmetric missions or tasks, and the *Tyranny of Distance* it is important that we recognize the need to ensure that we can join forces with our allies in order to meet today s threats as we attempt to prepare for an uncertain future. Figure 1 depicts, the importance of recognizing that our supply needs may change as our situation changes.



Where is our resupply of Bullets ?

Hey! They re lighting their arrows !!
Can they DO that ?

I think we need a couple of fire extinguishers !!

What are the chances that our prime vendor s *just in time* supply will get the fire extinguishers to us in time ?

Fig. 1: The changing environment

Balance — Requirements verses Resources

In order to ensure the maximum availability of material, personnel and equipment required to meet the current and future threats to global security, the Department of Defense must evaluate all potential threats and analyze the resources required to neutralize, minimize, or eliminate those threats. We must also recognize that previous defense strategies may not work in the future. As an example we can no longer count on our strategic forces to deter a foreign power from a first strike attack. Likewise, increased use of chemical and biological weapons by military, para-military, and others is an indication of vulnerability which places new demands on governments to provide protection for the general population. Finally, the increasing complexities of an urban battleground add to the need for a greater balance of requirements to resources and the essential availability of real time knowledge to optimize the warfighter s decisions.

Force structure

In order to ensure that the warfighter has the maximum number of options the DOD must have a well defined, trained and ready force, whose capabilities are understood and can be relied upon to be available when required. Unfortunately, as resources become more scarce the Force Structure must become more flexible in order to respond to increased missions. In the U.S. Navy this has resulted in fewer platforms being built and available, while adding weapons or mission response capabilities of those platforms. Add to this the challenges of being prepared to meet any mission on a moments notice, ensuring increased system reliability, maintenance and support for current equipment, systems and personnel; there is an increasing need to ensure that we optimize the resources and remain focused on the mission. While platforms and weapons systems are needed to meet current and future challenges, we must ensure that these systems are fully operational when required. This effective balance of current and future force requirements is challenging when the resource acquisition process is as lengthy and complex as the federal government s Planning, Programming, Budgeting System (PPBS).

Resources

The PPBS process normally focuses on a five year requirements plan. It starts at the activity level and must go through numerous management layers before the President submits the budget to congress for review, authorization to spend and appropriation. This lengthy process requires the DOD to either do without certain capabilities for several years, realign funds from adequately funded programs, or a combination of the two.

The impacts can be significant when plans are delayed, requirements are changed, or projected costs are not accurate. In addition, many organizations within the DOD, have their own focus and do not always share information or collaborate on key initiatives. A major ship repair function (overhaul) that is deferred from one year to the next, can have an impact to fleet readiness and capability in a numbers of areas. Such a decision by one accountable organization can pass additional resource implications to another. When a scheduled overhaul replaces a major weapons system (e.g. new radar), the system must be tested in an operational environment and the operators trained on it s effective use. This requires school house training, range facilities, real world training scenarios, and adequate time to hone the necessary skills to optimize system performance. It is also unreasonable to assume that every system will perform exactly as envisioned or that the design was fully functional at time of installation; which would necessitate a reallocation of resources and potentially impact to deployment patterns. In each case resources will need to be redirected from other program areas in order to ensure proper performance.

Recent General Accounting Office (GAO) audits of spare parts cost analysis have indicated that our projections have not been accurate and that our information systems do not provide an adequate audit trail to validate spending. Over the period 1994 to 1999 Navy-managed aviation parts increased at an average annual rate of 12%. Over the same period, when prices of high volume demand items were reviewed, it was noted that the average annual rates increased by 27% (Zuckerstein et al. 2000). In recent years congress has provided supplemental funding to meet many of the shortfalls resulting from inaccurate projections. In order to ensure that the funds were being spent for their intended purposes GAO was asked to review DON accounting records. The review indicated that there was inadequate information to verify how the increase in funding had been spent (Overton et al. 2001).

Although funding is required to meet the DOD s goods and services requirements Dollars don t fix broken systems material and people do. It is important that we turn our attention to material requirements and the resources necessary to have the right material, in the right place, at the right time.

Logistics

I don t know what this logistics thing is that Marshall keeps talking about, but I want some of it! Admiral Ernie King — 1942

The area of logistics brings together the disciplines of staffing, training, warehousing, inventory management, transportation, procurement, repair, and maintenance. While most requirements can be satisfied by financial resources, there may be some instances where all the resources in the world will not allow actions to be taken within the desired timeframe. Therefore it is essential that an effective information/knowledge management system be available to meet the demands of complex logistics requirements.

Inventory Management & Storage

In order to ensure that material is available to the customer, whether in maintenance (a repair part) or as a consumable (food, fuel, paper towels), warehouse and inventory management personnel must have a good understanding of future demand. If a ship consumed $546,000 in fuel during underway operations last month but is going to be inport for the next six months there is little need to warehouse a large quantity of fuel. Inventory managers and procurement agents need to know ships operating schedules in order to ensure proper material is available either from on-board inventory or government/commercial sources. Likewise if the Ships Engineer is planning to clean the fuel storage tanks, the inventory manager needs to ensure that he can remove or not replenish fuel out of or into that storage location. The significant challenge to material availability is a through knowledge of the anticipated demand for that material and the logistics network s ability to provide that material.

New or repair existing

One of the essential elements in effective inventory management is the ability to evaluate and predict future requirements. Although prior demand history may provide a good starting point for the 75% solution, greater predictability is required in order to ensure proper decisions are made. It is equally important that we have accurate and unbiased information. As previously stated there are two major categories of material, repair and consumable. There is little flexibility in obtaining new consumable items, one must go to the manufacturer; but there are several options available to our modern military forces with respect to repairable items. Historically the navy has recognized three levels of repair and maintenance; Organizational (O), Intermediate (I), and Depot (D). When we consider which level of repair/maintenance is appropriate, we evaluate the performing activities capability to complete the task. The typical limiting factors are; lack of skill, lack of material, lack of facility, lack of equipment, or lack of knowledge. In order to repair system components or maintain systems we must understand the meantime between failure, the length of service of the affected component or system, and the anticipated replacement/service life. As we will see naval aviation readiness data indicates that we have not solved the problem.

Figure 2 highlights the number of different Naval Aviation supply parts that are managed by government parts item managers. As the left pie indicates 76% of the material is managed by the Defense Logistics Agency (DLA), however it is important to note that the high cost items required to support naval aviation are Navy managed. The center pie depicts the 164,000 parts managed by Navy, 75% of those items had zero demand from all Naval sources (Navy, Marine Corps, and Naval Reserve) while 8,330 items had only one demand. The balance of the Navy-managed items 31,400 had greater than one demand, unfortunately 29% of those items were in backorder status at the end of the year.

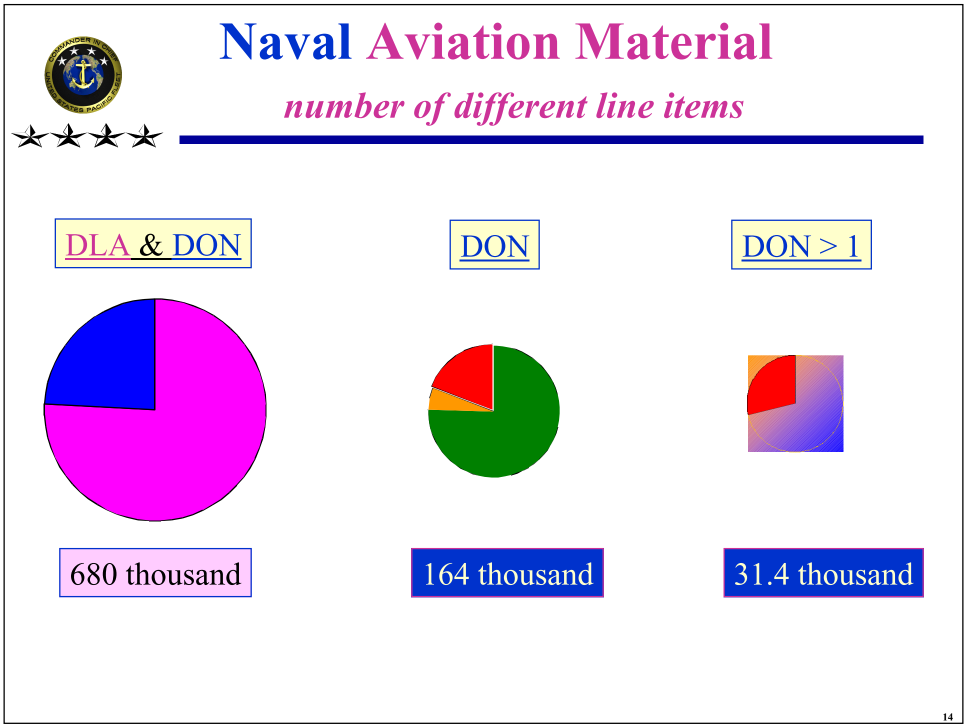


Fig. 2: Number of Aviation Line Items managed by DLA (76%) & DON (24%); FY-00 DON Aviation Material with Zero demand (75%), 1 demand (8%), & >1 demand (17%); and requisitions filled in FY-00
(71%), & on backorder at year end (29%).

Delivery and Transportation

A recent study by navy inventory managers found that it takes an average of 39.4 days for a repairable item to be received at the designated repair site. The proposed solution, developed by a logistics stovepipe organization, without the participation of the fleet customer, will utilize express air freight services from the commercial contract transportation network. This solution fails to acknowledge that the customer is extremely mobile, and may have already contracted for government transportation to move passengers, equipment, or other supplies. We must also recognize that capabilities which exist today in the private sector may not be available in the future. The first American victory in the revolutionary war was against an *outsourced* army, when George Washington defeated the Hessians at Trenton. Modern *Just in Time* inventory management practices in private sector work best in fairly stable production processes, but tend to break down when used in a more dynamic environment (Noreen and Garrison 1997).

From 1992 — 1999 we saw flight operations reduced by 30% (Hall et al. 2001) this was in part because of the lack of funding but more importantly the lack of material. As previously stated the most important element of the logistics equation is the ability to have the material available when and where required. This challenge must be met with the effective integration of the entire logistics process both maintenance and supply. The maintenance organization must be able to identify when and where maintenance must be performed and the supply process must ensure that the production/repair, warehouse, and transportation capabilities are available to meet the demand. In order to be successful we must break down stovepipe processes and ensure that information and knowledge is available to all appropriate stakeholders.

Disparate information sources

In this environment of increasing threats and limited resources it is essential to bring together information from the numerous stakeholders and the legacy systems that had evolved out of developing processes and management information systems, without the benefit of a strategic focus to bring them all to a common solution. The Defense Reform Initiative Directive #47 (DRID 47) identified the need for the DOD to operate in a shared electronic data environment. The final report identified the need to effectively integrate knowledge based solutions and the need for the seamless exchange of information (Hambre - 2000).

This resulted in the Department s focus on the need to move toward an Enterprise Resource Planning (ERP) solution used by many of the leading global corporations to standardize business processes, application software, and facilitate a change management process. The cornerstone of the ERP process was the migration of numerous legacy information systems to standard applications using common data elements across all business applications. Current estimates are that the ERP process will take 8-10 years to complete and will cost the Navy in excess of $1.8Billion.

As figure 3 indicates there are many elements of the supply portion of the logistics process each with their own link to meaningful information. Should the links break information will be lost and sub-optimized solutions developed. Figure 4 shows that there are many stovepipe organizations that do not adequately share information with one another creating many instances where stakeholders are not coordinating their actions with one another. This ultimately has a negative impact on the fleet which is responsible for providing trained and ready forces to meet any possible mission task.

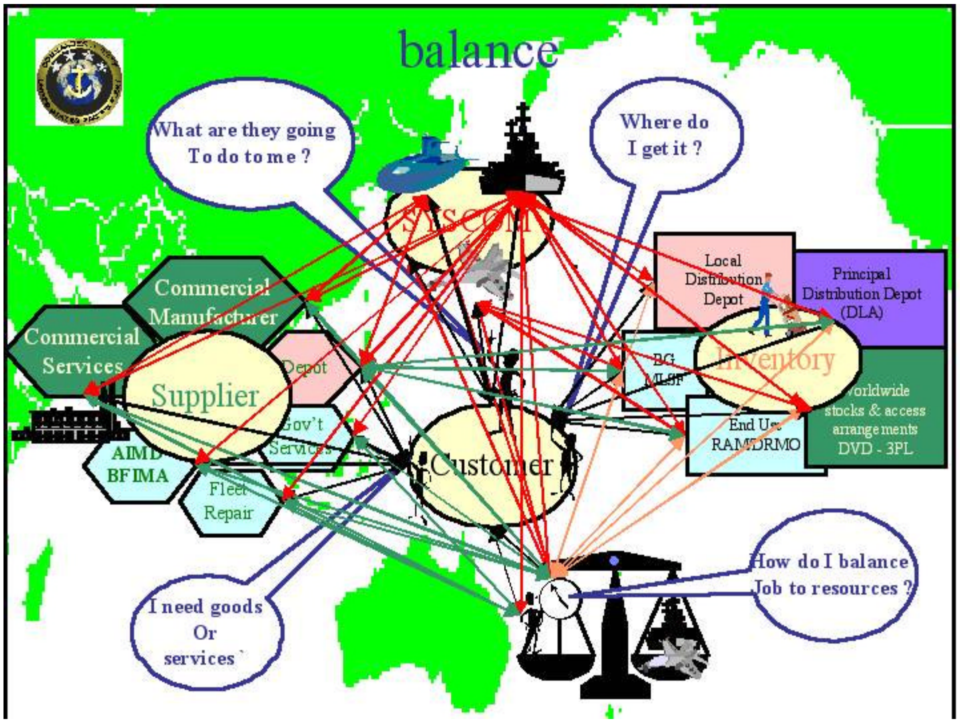


Fig. 3: Conflicting demands and complex links.

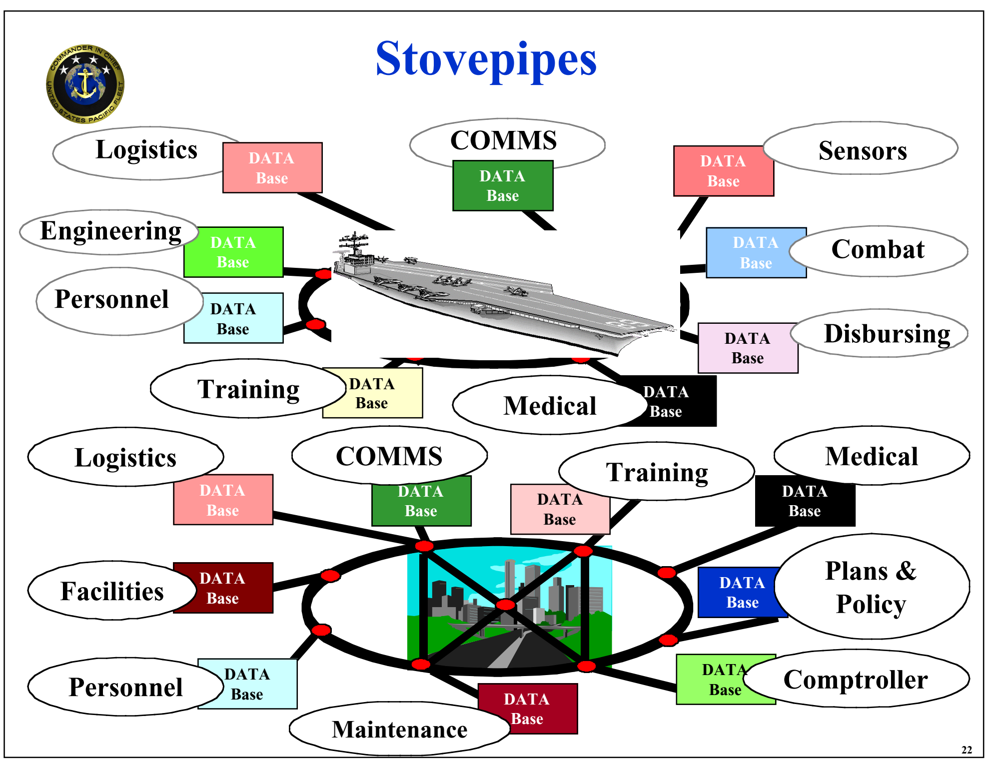


Fig 4: Isolated communities of practice.

Solution

The significant problems we face cannot be solved with the same level of thinking that created them. Albert Einstein

In his paper Information-Centric Decision-Support Systems: A Blueprint for Interoperability , Dr Jens Pohl highlights the importance of creating a decision support environment where computers can focus on the functions that they perform best, and humans can collaborate in the decision process with the requisite knowledge to optimize the solutions. Truly optimized decisions can be made once the human computer partnership has been established and organizations have progressed to an environment of Business Intelligence which brings together effective, computer-assisted (agent), information management and knowledge building (Pohl - 2001). Figure 5 depicts the need to migrate from data to understanding in order to ensure better decisions are made.

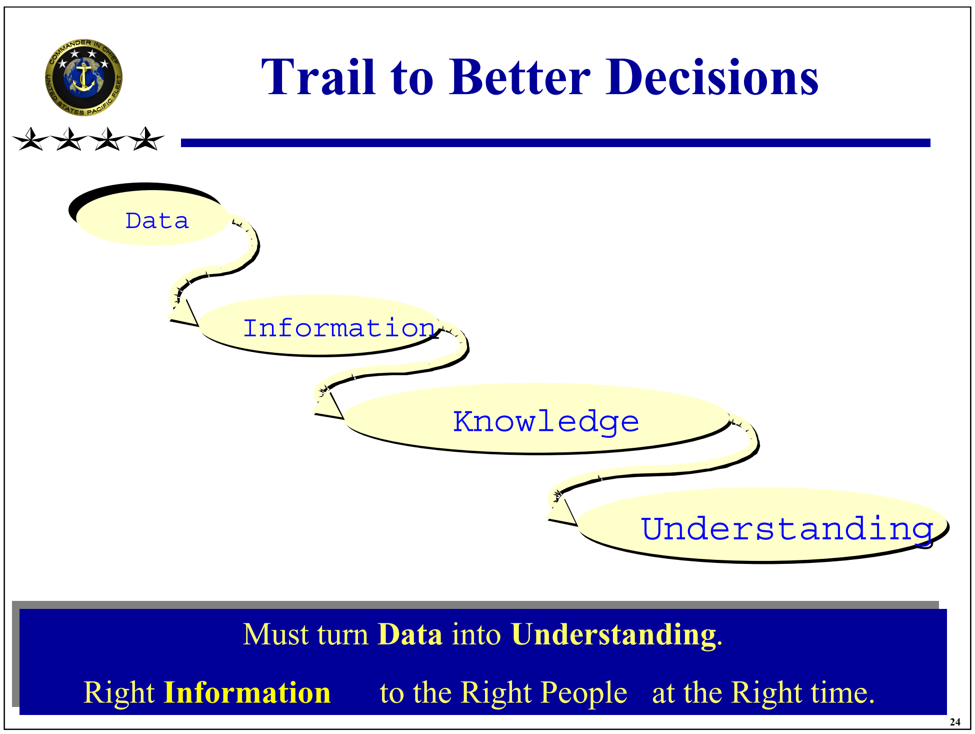


Fig. 5: Trail to Better Decisions

Dr. Philip Abraham the Logistics Program Manager for the Office of Naval Research, has recognized the need to bring various logistics projects and initiatives together for a common readiness focus. He has asked fleet representatives to participate in design specifications, program reviews, requirements definition, and integration efforts. There are two decision support projects that utilize agent based capabilities to provide a collaborative interactive tool to support fleet operations. The Shipboard Integrated Logistics Support (SILS) brings together numerous shipboard logistics R&D efforts in order to provide Commanding Officers with a balanced table top of information for optimized decisions. This project focuses on many of the elements of Admiral Natter s Strategic Planning Guidance. Both of these projects have included key operational personnel in the development of a proof of concept and this participation should help to facilitate the transition of the projects through the PPBS process to ensure fleet support, as they migrate to operational status.

Future

Changing requirements challenge the logistics community to ensure that adequate inventories available when needed. This will necessitate a need to anticipate future requirements, tasking, capabilities, and sources of supply. Agents provide an excellent opportunity to bring balance to our information needs and ensure that all stakeholders are working from a common data/information source. Within the Pacific Fleet there is a need to also be able to collaborate with our allies and sister services in order to meet anticipated regional threats.

A recent CINCPACFLT Logistics partnership was created to prototype a maintenance, supply, transportation, and repair process that would allow repairable items to be screened, repaired, and certified at a local level without the need for costly transportation, long lead time, and expensive depot overhead and repair. This initiative is expected to not only save repair funds but reduce the need for high inventory outlay; while increasing material readiness and providing more meaningful shore duty assignments for qualified military personnel One of the critical success factors is the effective integration of information and the availability of that information to the appropriate decision makers.

Figure 6 displays an information network that ties together the key logistics elements of fleet operations with the capability to focus on the critical information in the decision making process.

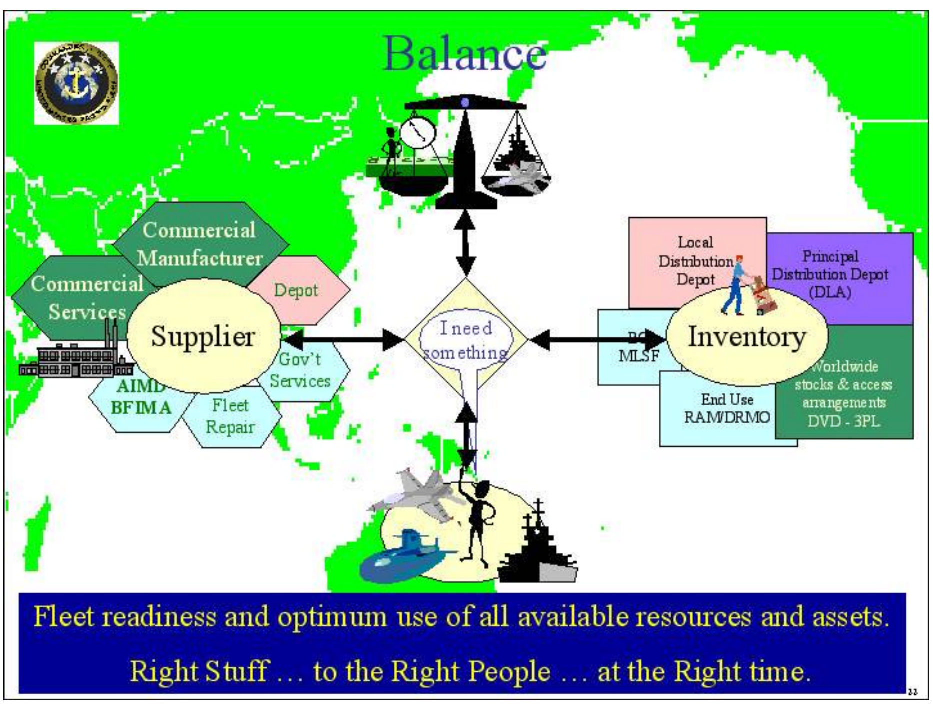


Fig.6: Achieving a Balance

Once this network is in place, collaboration can occur and communities of practice can come together to support decisions based on related functional information. Figure 7 highlights a streamlined organization and information network that allows for true collaboration to occur with the numerous and varied stakeholders.

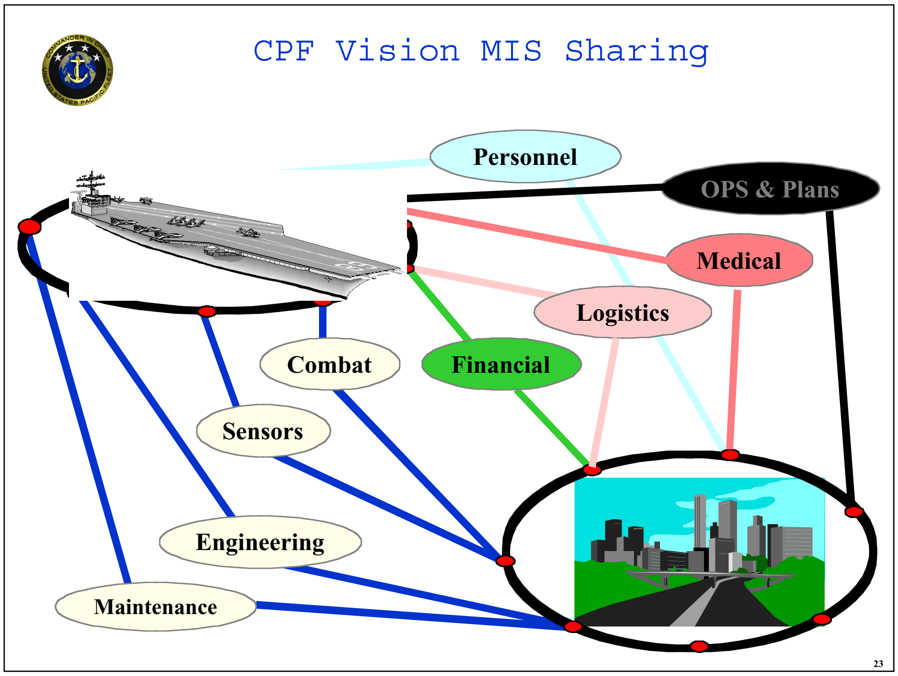


Fig.7: Enhancing Communities of Practice

Summary

Changing requirements, an uncertain future and limited resources challenge us to do more with less. It is more important than ever that we anticipate our future material requirements in order to ensure that equipment and personnel perform as required. As the U.S. continues to be a global partner in the world we must maintain strong ties with our allies to maintain free and open access to global commerce. Likewise our humanitarian interest place additional demands on Naval Forces. The critical catalyst is meaningful, accurate, and timely information. As we become exposed to more and more information, intelligent agents can help the decision maker focus on the information required for a particular decision and prioritize the balance. Failure to manage information will result in sub-optimized solutions that could also result in loss of valuable material and personnel assets. Failure is not an option. Figure 8 depicts an optimized decision support process that brings together the various information sources that are essential to an optimized decision.

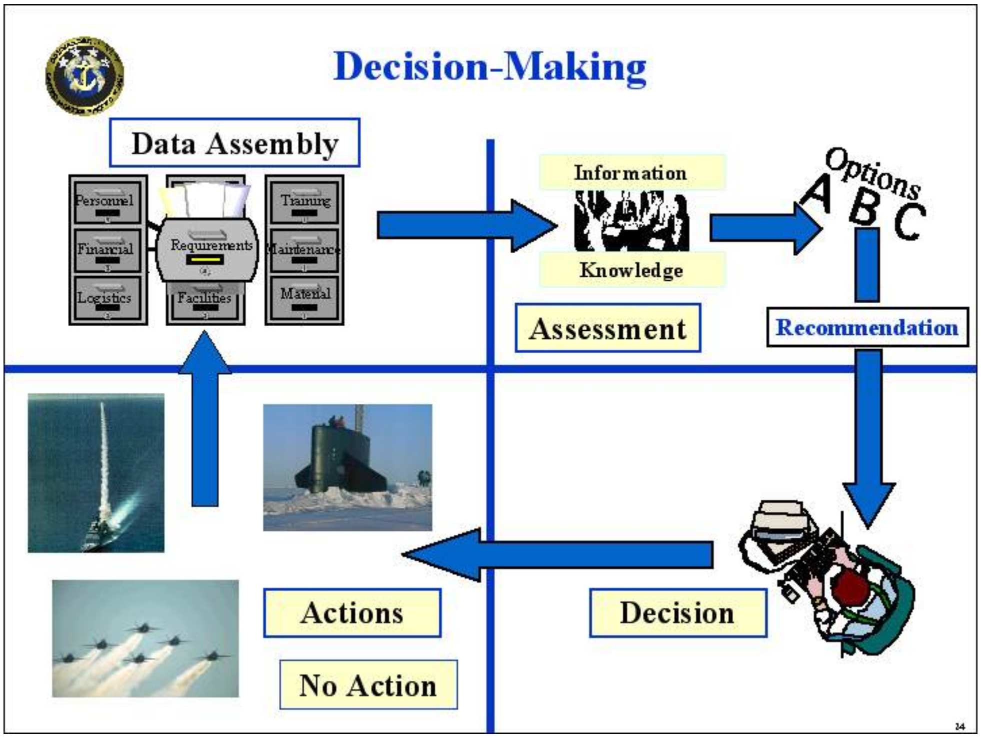


Fig.8: Proper Assessment results in better decisions and Actions

On November 30, 1942 the U. S. Navy s Task Force 67 made up of four heavy cruisers (Minneapolis, New Orleans, Pensacola, and Northampton), one light cruiser (Honolulu), and six destroyers (Fletcher, Perkins, Maury, Drayton, Lamson, and Lardner) steamed through the Soloman Islands to attack a Japanese resupply force heading for Guadalcanal. The U.S. Forces were well prepared, a plan had been developed based on lessons learned from previous naval engagements, and the men embarked were at battle stations.

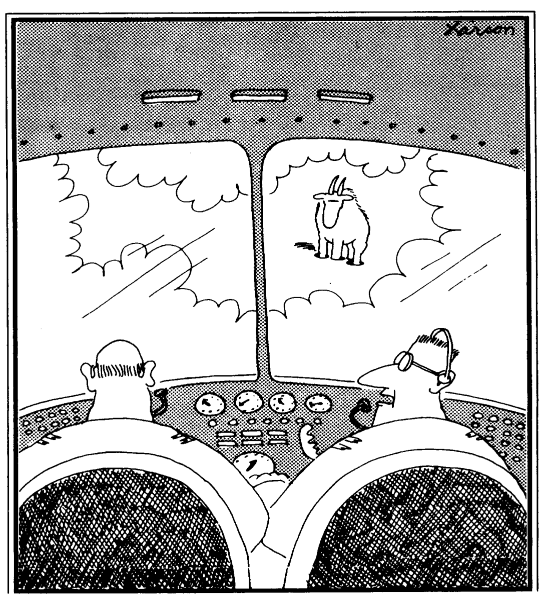
At 2310 the lead ship (Fletcher) identified a Japanese target using it s new high tech radar and six minutes later requested permission to fire torpedoes. At 2320 Commander, Task Force 67 granted permission to fire, unfortunately the Japanese force had closed to 7,300 yards, a distance that would enable their weapons to reach TF-67. Within a minute the U.S. Commander ordered the heavy guns on his cruisers to open fire, before the torpedoes had a chance to reach their targets. By daylight TF67 had sunk 4 Japanese DD s, and damaged 2 more, the U.S. had lost Northampton, and Pensacola, New Orleans, & Minneapolis were heavily damaged. New Orleans was struck by a Japanese torpedo hitting the forward ammunition compartment and ripping the bow off at the number two 8 gun mount. The three cruisers were repaired and returned to action in other naval battles, however the 413 men that lost their lives that night would not return to fight again.

The advantages of hindsight provide an opportunity to evaluate if better U.S. decisions could have been made. Although the decision to delay firing on the Japanese force may have had impact, there were many other factors outside the control of the on scene personnel that played an even greater role in the outcome. Radar was a new technology that had been deployed to our fleet and there had not been adequate familiarization with it s capability or reliability. (USS New

Orleans had Radar installed after the attack at Pearl Harbor) The use of smokeless gun powder may have provided some advantages but the bright flash that emitted from the gun barrels at midnight proved to provide an excellent visual bearing for reactive enemy actions. The Japanese forces did not have the advantage of Radar and relied on visual references and high resolution optics for their fire control solutions.

However the most critical problem may have been associated with U.S. torpedo development. Prior to the war the Navy s ordnance bureau had developed a faster, longer range torpedo. Unfortunately, the entire end-to-end capability of the weapon system was not fully tested prior to deployment, and critical design flaws in the exploder mechanism resulted in weapon failures. At the beginning of the war a naval officer from the Bureau of Ordnance visited Professor Albert Einstein to demonstrate the new technology. Professor Einstein informed him after a brief review, that the exploder mechanism had a design flaw that would preclude the firing pin from performing properly. The next day Einstein provided a sketch of a modification that would allow the firing pin to perform as it should. It is also important to note that the U.S. Submarine force had been experiencing similar problems with torpedoes malfunctioning. Rear Admiral Charles Lockwood (COMSUBPAC) in 1943 provided detailed experiments on torpedo performance to prove the design flaw, unfortunately it was not until 1944, long after the major and significant naval battles of the Pacific were over, that the problem was corrected. (Crenshaw —1995)

As future Naval Commanders seek to ensure program balance it is imperative that objectives, visions, missions, roles, and responsibilities are kept in perspective, we must focus on our collective missions and never lose sight of the importance we play in support of our National Security Strategy (Figure 9 pertains).



"Say . . . What's a mountain goat doing way up here in a cloud bank?"

Fig.9: Keeping things in perspective

Author s Note: This paper is dedicated to Captain John L. Neff USN (Ret) who served from December 1941 to June 1972 and received his final honors in May 2001 during the preparation of this manuscript. For over 26 years he has asked how s the fleet ? . It is this background of love, devotion, honor, and respect that I acknowledge a man who inspired, directed, and encouraged me to focus on the fleet. To you Sir, I thank you for your constant presence in my life and appreciate the sacrifice you made during your naval career. I trust that the lessons learned from the evening of November 30, 1942 will be used to ensure that the fleet is prepared to go forward from the sea any time any place.

Reference:

Natter, R.J.(2000): Navy Strategic Planning Guidance, With Long Range Planning Objectives

Zuckerstein, K.S., Mackin, M, Tom, Y.W., and Perdue, C (2000): GAO 01-23 Navy Aviation Spare Parts

Overton, J.L., Wren, J.C., Reid, J.H., and Murray, J.F. (2001): GAO 01-472 Defense Inventory: Information on the Use of Spare Parts Funding Is Lacking

Noreen, E.W. and Garrison, R.H. (1997): Managerial Accounting: Concepts for Planning, Control, Decision Making Eighth Edition

Hall, J.P, Jondrow, J.M., Kirk, R.L, Measell, B.H., Shaw, G.B., Trost, R.P. and Ye, M (2001): Explaining the Rising Cost of Aviation Depot Level Repairables (AVDLR)

Hambre, J.J. (1999): Department of Defense Reform Initiative Directive (DRID) # 47: End-to-End Procurement Process

Pohl, J (2001); Information-Centric Decision-Support Systems: A Blueprint for Interoperability , ONR Workshop on Collaborative Decision Support, Quantico, VA, June 5-7

Crenshaw, R.S. Jr. (1995): The Battle of Tassafaronga, The Nautical and Aviation Publishing Company of America